ELECTRIC VEHICLE BATTERY CHARGING SYSTEM

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DECLARATION

"We hereby declare that this thesis is our original work and it has been written by us in its entirety. We have duly acknowledged all the sources of information that have been used in the thesis. The thesis (fully or partially) has not been submitted for any degree in any university or institute previously."

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SUPERVISOR’S APPROVAL

This is to certify that this thesis titled "**ELECTRIC VEHICLE BATTERY CHARGING SYSTEM**" was prepared by the following students under my direct supervision. This thesis work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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There are a number of people who have been significant in the culmination of this paper, both academically and actually.This work, and the time that we have spent in looking into the work, would have been a lot less fortunate without them.We owe them with a lot.

Dr.M.Bashir Uddin

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ABSTRACT

Every day, battery technology advances, and the pace of battery utilization rises. Battery usage will rise, especially as electric vehicles become more common. In general, battery-based systems are made up of a large number of battery cells. In systems with multiple battery cells, it is critical to ensure that the batteries can be charged and drained in the same amount in order to maximize total energy efficiency and extend battery life.The design is done in such a way that it detects the amount of charge stored in the battery and alters the charging voltage accordingly. Several safety precautions have been built into the design to protect both the battery and the charger. PROTEUS software was used to simulate the situation. The simulation results reveal that the design system charges the batteries efficiently and effectively. The model of the proposed paper is such that it is possible to increase or decrease the output voltage by reducing the duty cycle through variables. Since our lithium ion battery is 12 volts, we need to charge 20 percent more than the input voltage, so we have 14.5 outputs. The Voltage graph is shown in Figure 5.4. The y-axis shows the voltage values and the x-axis shows the simulation time values. The graph shows that the value of voltage rises straight up from 0.1 time point to 14.5 volt. So we can see from the graph that the output value of voltage is 14.5 volt. The current graph is shown in Figure 5.3. The y-axis shows the current values and the x-axis shows the simulation time values. The graph shows that the value of current is slightly curved upwards from 0.1 time point to 0.96 ampere. So we can see from the graph that the output value of current is 0.96 ampere. The value of the output current is less than 0.9 to 1 ampere.Every day, battery technology advances, and the pace of battery utilization rises. Battery usage will rise, especially as electric vehicles become more common.

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LIST OF ABBREVIATIONS

AC, Alternating Current
BEV, Battery Electric Vehicle
CV, Conventional Vehicle
DC, Direct Current
EDV, Electric Drive Vehicle
EREV, Extended Range Electric Vehicle
EV, Electric Vehicle
HEV, Hybrid Electric Vehicle
ICE, Internal Combustion Engine
KV, Kilo Volt
KVA, Kilo Volt-Ampere
KVAR, Kilo Volt-Ampere Reactive
KW, Kilo Watt
KWH, Kilo Watt Hour
MVAR, Mega Volt-Ampere Reactive
MW, Mega Watt
NHTS, National Household Travel Survey
PEV, Plug-in Electric Vehicle
PHEV, Plug-in Hybrid Electric Vehicle
PVUR, Phase Voltage Unbalance Rate
SOC, State of Charge

CHAPTER 1

INTRODUCTION

1.1Background of the Study

The transportation area is perhaps the biggest supporter of Green House Gas (GHG) outflows on the planet with fourteen percent and the second-biggest supporter of GHG emanations in our world [1]. However, this area is indispensable since it is a fundamental piece of our regular routines. The development that vehicles permit is vital for the acknowledgment of numerous exercises, hence lately, the utilization of vehicles has expanded. Consequently, fossil fuel byproducts and commotion contamination have expanded, and oil is running out soon. To save the environment and normal assets, electrical vehicles innovation is considered as the future method of transportation and presents a colossal chance to diminish GHG outflows. In view of fears with respect to the limit of electric power dissemination organizations and the lessening of petrol to deliver power, we can concede that electric vehicles are just supportable assuming the power used to charge them confesses all and efficient power energy that won't ever run out and won't ever cause hurt for nature.

In late many years, oil utilization in the transportation area has developed at a higher rate than in some other areas. The factual examination has shown that with the current pace of revelation of new oil holds and the current utilization rate, the world oil save will be drained by 2049 [1]. The increment in oil utilization has principally come from new requests for vehicles fueled by ordinary gas-powered motors. The huge usage of Gas-powered motor vehicles has contributed drastically to the contamination of the medium and huge urban areas [2]. Since the natural issues of the nursery impact and an Earth-wide temperature boost are straightforwardly connected with vehicle discharges, government offices and associations have created severe guidelines for fuel utilization and emanations [3]. In this situation, battery-fueled Electric Vehicles (EVs) appear to be an optimal answer for managing the energy emergency and an unnatural weather change since they have zero oil utilization and no outflows out and about. The zero neighborhood emanations and the quiet driving of electric vehicles are a couple of traits that can assist with reestablishing personal satisfaction in urban communities [2]. Given the short-range trips and successive unpredictable driving attributes of city driving, electric vehicles can convey execution like an Electric vehicle at decreased expenses contrasted with traditional gas motor vehicles under city driving [2,4].

Transportation and power age are viewed as the contributing variables to air contamination and an Earth-wide temperature boost. Actually, the vast majority of the power plants are worked for external the urban communities; accordingly, traditional gas vehicles are viewed as the essential driver of the defilement of air by smoke and destructive gasses in metropolitan regions. Regular vehicles (RVs) add a lot of air contamination consistently. For example, in the US, around 27% of dangerous atmospheric deviation contamination is brought about by gas vehicles, including vehicles, trucks, and transports [1]. Not exclusively do regular gas-powered motors add to natural contamination however they additionally consume an excessive amount of oil. Around 430 million gallons of oil are utilized each day to fuel regular vehicles [2]. The terrible outcomes of contamination have brought forth the jolt of transportation. Along these lines, electric vehicle innovation is a sign promising answer for tackling this issue [3]. This arrangement drives automakers to move and put resources into electric drive vehicles (EDVs) creation. In the last part of the 1800s, the principal business electric vehicle was sent off in New York City [4]. A short time later, the customary and new automobile producers entered the market of electric transportation. They contributed and gave their capability to the advancements that would prompt delivering zero or close to zero-emanation vehicles. Right now, module half and half electric vehicles 2 (PHEVs) decrease CO2 emanation by 25% contrasted with traditional vehicles [5]. A few examinations [6] demonstrated that per mile voyaged, power is a less expensive source than gas. Clean Edge Site [7] affirms that there will be around 2,000,000 electric vehicles (EVs) all around the world by 2015 while the US official homegrown is wanted to have 1,000,000 EVs by 2015. This has been upheld by the legislatures at all levels. Major automakers have brought EVs into the market. Chevy Volt vehicles have traveled 187-million electric miles. Makers making EVs, including Nissan, Tesla, GM, Honda, Toyota, BMW, Mercedes, and so forth have presented their PHEVs in the U.S. market. It has been anticipated that half of the new vehicles will be electric vehicles models by 2020 [8]. Since the market of EVs is developing quickly, challenges because of the entrance of the EVs should be researched. Hence, the infiltration of module electric vehicles (PEVs) into the power matrix is viewed as a subject this time. A large portion of the shoppers needs their PEVs' batteries to be charged when they return home after their functioning hours. Notwithstanding, in the event that all batteries begin charging simultaneously, accepting that they are at a completely released express, the pinnacle interest for the electrical matrix will expand, the circulation transformer would be over-burden, the power quality and the dependability of the entire framework would be debased, and the utilities' machines (for example three-stage enlistment machines), also as clients' hardware, could be possibly harmed. To defeat these issues, utilities need to support their age, transmission, and circulation framework. One more suggested arrangement is that the utilities would either apply monetary motivating forces for off-top charging or use EVs' savvy charging that empowers the correspondence among utilities and vehicles to control charging designs [9].

1.2Motivation for Research

According to [12], 70% of the population will reside in cities and make daily commutes of less than 100 kilometers. Vehicle emissions generated during these excursions can be considered a source of pollution in the environment. The low range of electric vehicles would not be an issue for daily driving because the bulk of daily travelis less than 100 kilometers (62 miles). City driving's frequent start and stop features are also beneficial in expanding the range of electric vehicles. Electric vehicles also provide a clean, emission-free mode of mobility. Increased electric power generation utilizing renewable energy resources such as solar power, wind power, and others, rather than thermal power, can alleviate the worry of indirect emissions associated with the increase in electric vehicles.

In urban driving settings, electric vehicles can give a comparable performance at cheaper prices than traditional vehicles. In comparison to any other available vehicle architecture, the study in [4] reveals that electric vehicles are the least expensive in terms of annual fuel costs. Figure 1.1 compares the annual operational expenses of several vehicle models [4].

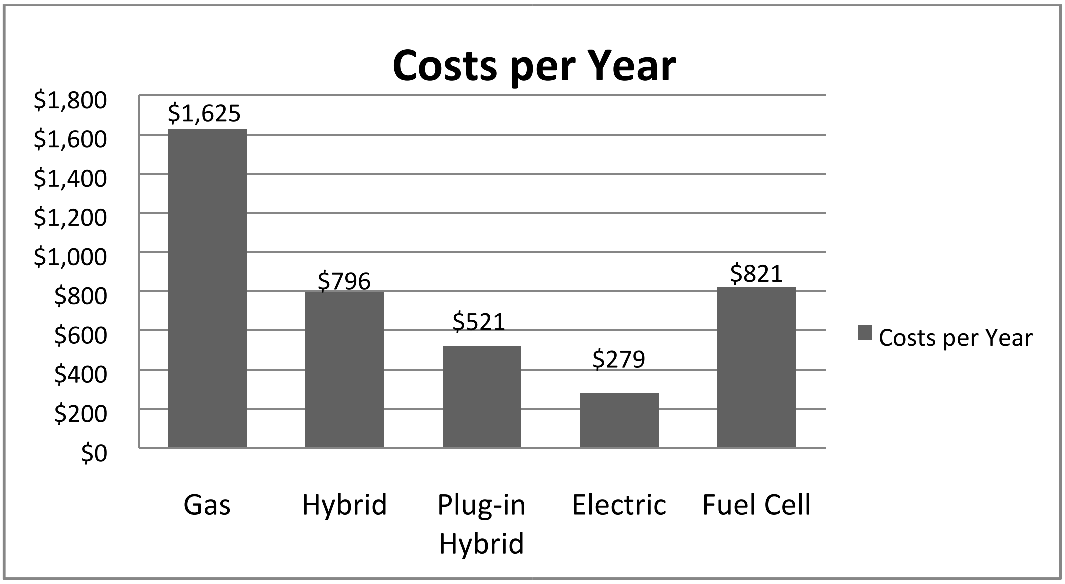


Figure 1.1: Different vehicle architectures of Annual operational cost comparison [4].

1.3 Objectives of the Study

The main objective of this project is to provide an electric vehicle cell testing platform and battery modeling. A new cell testing platform, in particular, is being developed as a strong tool for investigating the long-term capacity decline of Li-Ion batteries. Furthermore, to precisely estimate battery performance, a novel battery modeling approach is proposed. The proposed model is meant to be used in real-time batteries systems to improve vehicle performance even more. Although commercialized battery cell testers can be used to test batteries, they are not optimal for this task because high-power automotive-grade cells are employed, resulting in significant energy waste.

The main objectives of this thesis are:

- The goal of this thesis is to realize a simulation of an electric vehicle charging system.
- To provide a testbed based on a real-time digital simulator to assist distribution utilities in assessing the impact of incorporating electric vehicles into their distribution networks.
- To implement the proposed of EV battery charging system.
- It protects the battery cells from abuse and damage;

- It extends the battery life as long as possible;
- It makes sure the battery is always ready to be used.

1.4Thesis Methodology

The thesis was completed using a series of approaches that were followed in order. Initially, a charge controller design was created in the Proteus 8 environment. The proposed circuit's performance has been investigated under a variety of scenarios, including output voltage, input current, and so on. The features of several sensing circuits have been examined. The whole circuit's operation under various anomalous parameters has been studied. The equipment and their descriptions have been detailed. To determine the operational parameters of the designed circuit, the current and voltage ranges were examined.

1.5Outline of the Paper

This thesis consists of six chapters and one appendix.

Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Research Methodology and Calculation
Chapter 4: Motor Drives For Electric Vehicle
Chapter 5: How to Charge Battery
Chapter 6: Simulation Using Proteus
Chapter 7: Result and Discussion
Chapter 8: Conclusion and Future Recommendation
Appendix.

CHAPTER 2
LITERATURE REVIEW

2.1 Electric Vehicles (EVs)

An EV is an abbreviated abbreviation for an electric vehicle. EVs are vehicles that are either to some degree or completely powered by electricity. An electric vehicle (EV) is one that runs on an electric engine rather than a gas-powered motor that creates power by consuming a blend of fuel and gases. Accordingly, for example, vehicles are viewed as a potential trade for current-age cars to resolve the issue of rising contamination, dangerous atmospheric deviation, draining normal assets, and so forth. Although the idea of electric vehicles has been around for quite a while, it has attracted a lot of interest in the past ten years in the midst of rising carbon impressions and other ecological effects of fuel-based vehicles.

Electric vehicles have low running expenses as they have fewer moving parts to keep up with and are, furthermore, harmless to the ecosystem as they utilize practically zero non-renewable energy sources (petroleum or diesel). While certain EVs utilize lead-corrosive or nickel-metal hydride batteries, the norm for present-day battery electric vehicles is currently viewed as lithium-particle batteries as they have a more noteworthy life span and are phenomenal at holding energy, with a self-release pace of simply 5% each month. In spite of this better productivity, there are still difficulties with these batteries as they can overheat and cause flames or blasts in the Tesla Model, despite the fact that endeavors have been made to work on the security of these batteries.

2.2 Types of Electrical Vehicles

Electric vehicles (EVs) are vehicles that are powered entirely or partially by electricity. A battery for energy storage, an electric motor for propulsion, a generator, a mechanical transmission, and a power control system are all common components of an electric vehicle system [10]. The word "electric vehicle" refers to a variety of vehicle technologies. The most common types of electric vehicles on the market now are mentioned below.

2.2.1 Battery Electric Vehicles (BEVs)

A Battery Electric Vehicle (BEV), sometimes known as an All-Electric Vehicle (AEV), is a vehicle that runs solely on electricity. This type of electric vehicle does not have an internal combustion engine (ICE). Electricity is stored in a huge battery pack, which is charged by connecting to the power grid. The electric car is powered by one or more electric motors, which are powered by the battery pack.

Architecture and Main Components of BEVs

Components of BEV

- Electric motor
- Inverter
- Battery
- Control Module
- Drive train

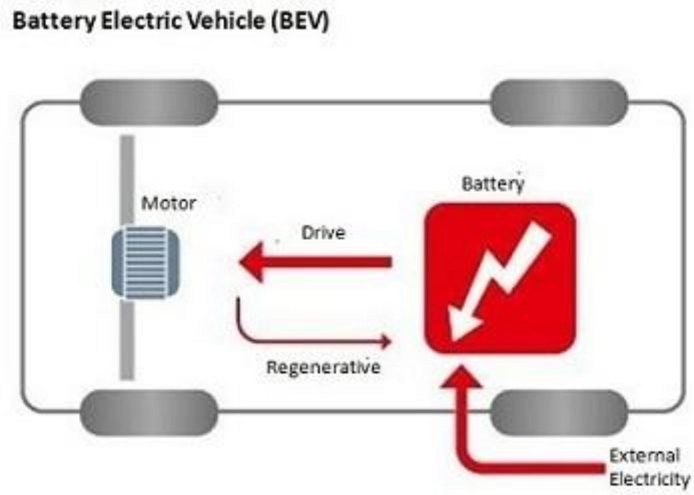


Figure 2.1: Architecture of BEVs

BEV Principles of Operation

- For the electric motor, power is transferred from the DC battery to AC.
- The accelerator pedal delivers a signal to the controller, which changes the frequency of the AC current from the inverter to the motor to adjust the vehicle's speed.
- Through a gear, the motor connects and rotates the wheels.

- The motor transforms into an alternator and creates power, which is delivered back to the battery when the brakes are applied or the electric car decelerates.

Simple battery electric vehicles are a type of battery electric vehicle. Unlike a hybrid, a BEV has no internal combustion engine and is thus entirely electric. It must be linked to the electrical grid for recharging after the limited driving mileage has been reached. BEVs require a bigger battery size and capacity (e.g., 25-35 kWh) because they are solely powered by electricity and can go 80 miles or more [11]. Although battery electric vehicles do not emit direct hazardous emissions of polluting gasses, the majority of power plants used to recharge BEVs are not renewable and emit greenhouse gases. Nissan began selling the LEAF battery-electric vehicle in the United States in late 2010 [10].

2.2.2Hybrid Electric Vehicles (HEVs)

The term "standard hybrid" or "parallel hybrid" is used to describe this sort of hybrid vehicle. HEVs have both an internal combustion engine and an electric motor. Internal combustion engines (gasoline and other types of fuels) provide energy to the internal combustion engine, while the motor is powered by batteries. The transmission, which drives the wheels, is rotated by both the gasoline engine and the electric motor at the same time.

The distinction between HEV and BEV and PHEV is that HEV batteries can only be charged by the ICE, wheel motion, or a combination of both. The battery cannot be recharged from outside the system, such as from the energy grid, because there is no charging port.

Architecture and Main Components of HEVs

Components of HEV

- Engine
- Electric motor
- Battery pack with controller & inverter
- Fuel tank
- Control module

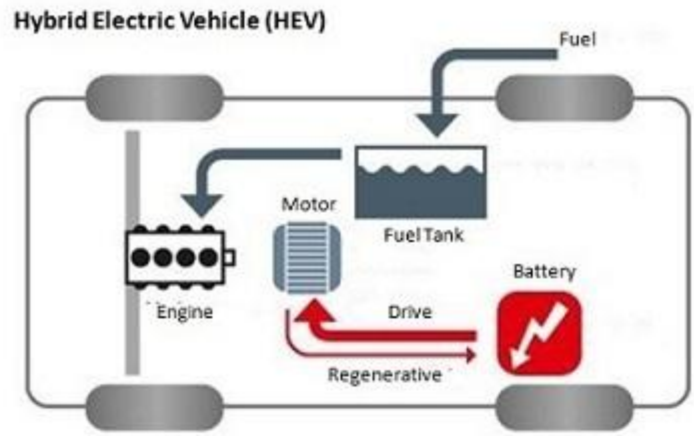


Figure 2.2: Architecture of HEVs

HEVs Operating Principles

- Like a typical car, it has a fuel tank that delivers gas to the engine.
- It also contains a battery pack that powers an electric motor.
- The transmission can be turned by both the engine and the electric motor at the same time.

A hybrid electric vehicle (HEV) is an electric vehicle that combines a gasoline engine with a battery-powered electric engine. The majority of the battery charge comes from the gasoline engine when driving, with a little amount coming from regenerative braking because the vehicle's kinetic energy is absorbed and stored in the battery rather than being wasted as heat and friction. In comparison to conventional autos, the battery in HEVs improves fuel efficiency by 25%. The Toyota Prius is a hybrid vehicle that runs on both gasoline and electricity [10].

2.2.3 Plug-In Hybrid Electric Vehicles

A PHEV is a hybrid vehicle that has both an internal combustion engine and a motor and is also known as a series hybrid. This sort of electric vehicle offers a variety of fuel options. This type of electric vehicle is propelled by a rechargeable battery pack with a conventional or alternative fuel (such as bio-diesel). Electricity can be used to charge the battery by plugging it into a wall outlet or an electric vehicle charging station (EVCS).

In most cases, PHEVs can operate in at least two modes:

- All-electric mode, in which the car's energy is supplied entirely by the motor and battery.
- Hybrid Mode: This mode uses both electricity and gasoline.

Some PHEVs can travel over 70 miles solely on electricity.

Architecture and Main Components of PHEVs

Components of PHEV

- Electric motor
- Engine
- Inverter
- Battery
- Fuel tank
- Control module
- Battery Charger (if onboard model)

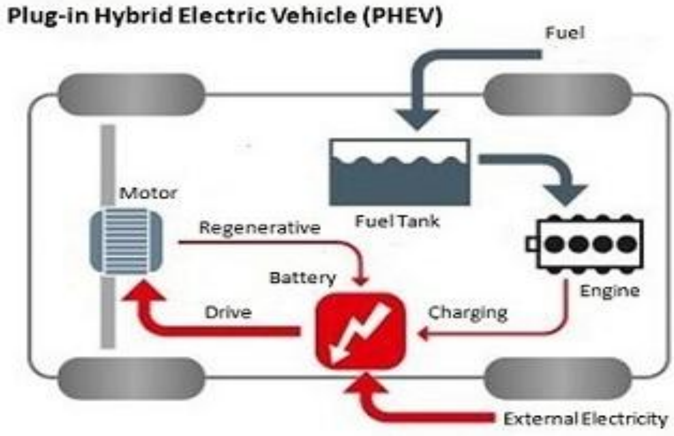


Figure 2.3: Architecture of PHEVs

PHEVs Principles of Operation

PHEVs usually start in all-electric mode and run on energy until the battery pack runs out. When a vehicle reaches highway cruising speed, which is usually around 60 or 70 miles per hour, some vehicles switch to hybrid mode. When the battery runs out, the engine kicks in and the car becomes a traditional non-plug-in hybrid.

PHEV batteries can be charged by an internal combustion engine or regenerative braking in addition to hooking into an external electric power source. The electric motor acts as a generator during braking, utilizing the energy to charge the battery. As a result of the electric motor supplementing the engine's power, smaller engines can be employed, improving fuel efficiency without sacrificing performance.

A PHEVs is nearly identical to today's hybrid electric vehicle. An energy storage battery, an electric drive train, and a conventional internal combustion engine (ICE) for propulsion, as well as a power control system, may be included in its components [10]. It has a greater battery capacity and can be recharged by plugging it into an external power source. PHEVs can be driven for extended distances because gasoline is considered a backup resource. When the state of charge is high, they run up to 40 mph on electricity, then switch to the internal combustion engine for the remaining distance.When evaluated as electrical loads on the distribution system, PHEVs and BEVs are comparable, yet their operational characteristics are vastly different. PHEVs are less petroleum-dependent than HEVs [12]. Furthermore, PHEVs are predicted to be capable of driving regular daily mileage only on electricity.

2.3History of Electric Vehicles

The history of electric vehicles dates back to the mid-nineteenth century, and numerous innovators are credited with the development of the electric car. nyosJedlik, a Hungarian who constructed an early sort of electric motor, created a miniature automobile model powered by the then-new type of engine in 1828. Thomas Davenport invented the first American DC electric motor in Vermont in 1834. It wasn't until 1840 that rechargeable batteries became a viable technique to store electricity in vehicles.

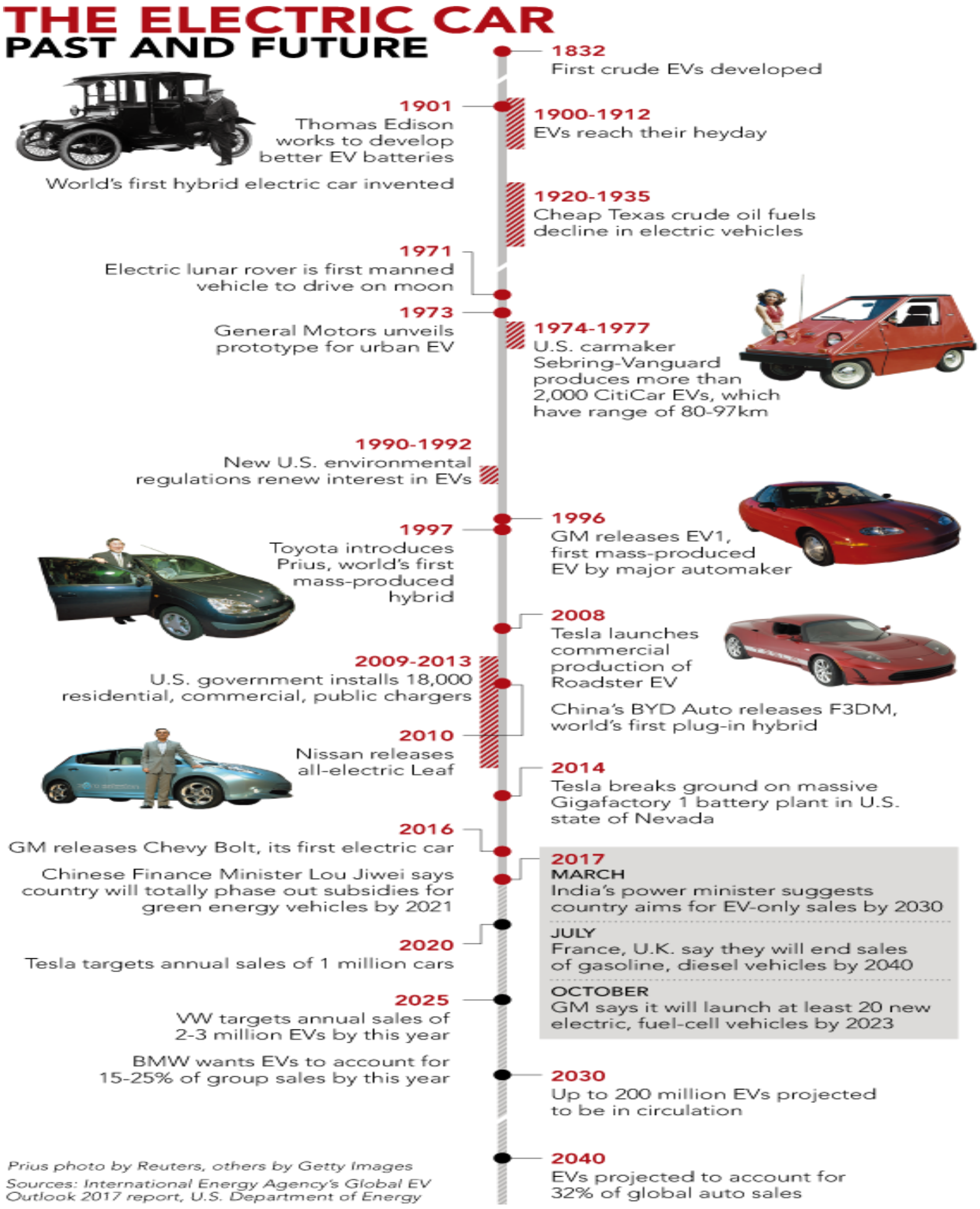


Figure 2.4: Timeline of EVs

With the efforts of Gaston Plante and his countryman Camille Faure, superior battery technology was invented in France in 1881, paving the path for electric vehicles and their development in Europe. The first countries to promote the development of electric vehicles were France and the United Kingdom.

Prior to the advancement of the internal combustion engine, electric automobiles set numerous speed and range records. On April 29, 1899, he set a new world speed record at

100 kilometers per hour. Despite the fact that Thomas Davenport was one of the first to incorporate an electric motor into a vehicle, the electric car in the traditional sense did not emerge until around 1891.

Figure 2.5: Lohner-Porsche Electric Coupe, the year 1899

Source: Electric and Hybrid Cars, Curtis D. Anderson and Judy Anderson

Figure 2.6: Woods' Victoria Hansom Cab, year 1899

Source: Electric and Hybrid Cars, Curtis D. Anderson and Judy Anderson

Figure 2.7: German electric car, the year 1904

Source: The German Federal Archive, www.wikipedia.org

The highest speed of the first electric cars was around 32 km/h due to mechanical limitations. Despite their slow speed, electric cars had a number of benefits over their competitors at the turn of the century. They didn't produce the vibrations, scents, or noise that gasoline-powered cars do. Changing gears was the most difficult component of driving in petrol-powered cars, while electric cars did not require gear changes. The restricted range of electric automobiles was unimportant to wealthier clients who drove them solely in city traffic. Electric cars also have the advantage of not requiring any manual effort to get started. Cars with gasoline engines featured front-side handles for starting the engine, which required a significant amount of force. Due to their ease of operation, electric automobiles were frequently marketed as vehicles appropriate for female drivers. Early electric vehicles were also referred to as "women's vehicles”.

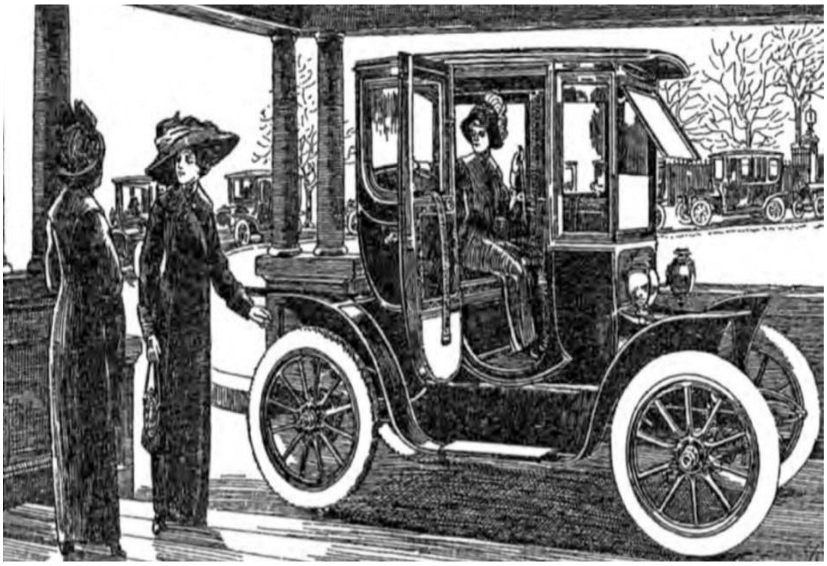


Figure 2.8: Columbus Electric Coupe, the year 1912

Source: Electric and Hybrid Cars, Curtis D. Anderson and Judy Anderson

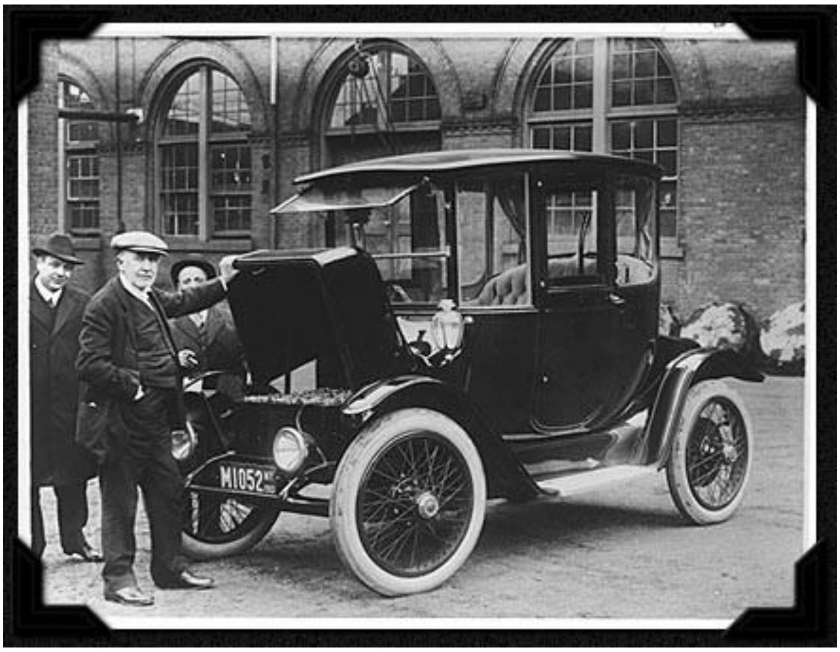


Figure 2.9: Thomas Edison with his electric car, the year 1913

Source: http://upload.wikimedia.org/wikipedia/commons/8/8a/EdisonElectricCar1913.jpg

At the turn of the century, steam-powered 40% of American cars, electricity-powered 38%, and gasoline-powered 22%. The majority of the early electric cars were huge, with lavishly built wagons and opulent interiors filled with expensive materials. These automobiles were designed for the upper class of highly wealthy clients who wanted to stand out by purchasing one. Electric cars start at roughly $ 1,000 (approximately $ 28,000 today) and average at $

3,000 (approximately $ 84,000 today). The popularity of electric automobiles peaked in 1912.

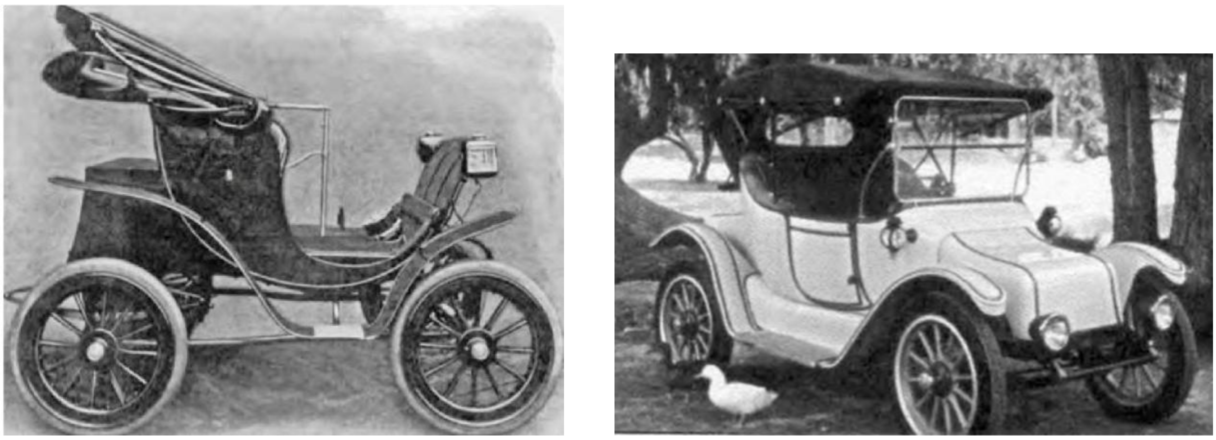


Figure 2.10:Electric Victoria, year 1902; Detroit Electric Roadster Model 46, year 1915

Source: Electric and Hybrid Cars, Curtis D. Anderson and Judy Anderson

Figure 2.11:Milburn Coupe, year 1915; **Detroit** Electric Coupe, year 1917

Source: Electric and Hybrid Cars, Curtis D. Anderson and Judy Anderson

Figure 2.12:Charging of electric car in Detroit, year 1919

Source: Library of Congress, http://www.loc.gov/pictures/resource/cph.3b16781/

In Great Britain and Europe, the First World War created a large demand for electric cars. In 1914, the total number of electric vehicles in Europe was estimated to be around 3,200. (Cars, buses...). Electric vehicles for commercial use were mostly made in Europe. Electric vehicles' safety, simplicity of design, and ease of operation made them vehicles that even untrained and new, young drivers could use. After the war, Norway and Sweden had a significant fleet of commercial electric vehicles on the market and a large energy hydro potential, making them very viable markets. Italy also uses hydropower to create electricity, making it a prospective market for electric vehicles. Electric vehicles were being exported in considerable quantities by Australia, Japan, Mexico, and France, and their future looked bright because demand was enormous.

Electric automobiles began to lose their market share after their first triumph at the turn of the century. This was the outcome of a chain of events. Route infrastructure was built and the road between American cities was opened in the 1920s of the nineteenth century. To use these routes, a vehicle with a longer range than electric vehicles was required. Fuel became widely available and affordable after substantial oil reserves were discovered in Texas, Oklahoma, and California. The utilization of electric vehicles was restricted to metropolitan conditions due to their low speed (not more than 24-32 km/h) and extremely restricted reach (50-65 km). Petroleum fueled vehicles were presently ready to travel further and quicker than comparable electric vehicles. In 1912, petroleum fueled vehicles became more straightforward to drive because of the innovation of Charles Kettering and his electric "starter", which wiped out the requirement for a handle to turn over the petroleum motor. Commotion likewise became endurable because of the silencer, designed by Hiram Percy Adage in 1897. At last, the beginning of large scale manufacturing of vehicles with petroleum drive was started by Henry Portage. In 1915, the cost of his vehicle was $ 440 (today this is about $ 10,000), and after a year it even tumbled to just $ 360 (today this is about $ 7,700). Interestingly, the cost of comparative electric vehicles was all the while expanding. In 1912, the cost of an electric vehicle was roughly $ 1,750 (today this is about $ 42,000). How did Henry Portage transform the then second rate vehicle into the market chief? Not utilizing innovation, yet utilizing a superior business strategy. He comprehended the idea of the market and expected to be that assuming individuals saw more Portage vehicles on the road they would need to purchase the Passage brand. Minimal expense of vehicle creation and their accessibility sent off a torrential slide of interest. On 31st July 1971, electric vehicle turned into the principal vehicle the man drove on the moon thus it got became unmistakable from any remaining vehicles. It was the Lunar Meandering Vehicle, first conveyed during the Apollo 15 mission. "Moon Buggy" was created by the organizations Boeing and Delco Gadgets.

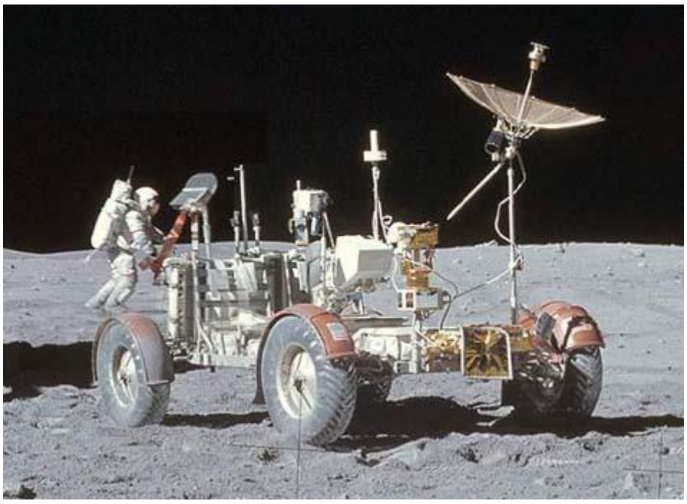


Figure 2.13:Lunar Roving Vehicle

Source: http://en.wikipedia.org/wiki/Lunar_Roving_Vehicle

Albeit quite a while passed without public consideration, the energy emergencies of the seventies and eighties prompted recharged interest in electric vehicles.

The Green development in the ‘90s and toward the start of the 21st century made driving a harmless to the ecosystem vehicle the political and style articulation. Security and protection of the world's regular assets have worth, and contamination is hurting us all. Ecologically mindful customers overpowered the market. The development of a framework for charging vehicles, expanding motivations for the buy, and empowering the green idea in open life could reestablish the electric vehicles their fame of the nineteenth century.

At the hour of sending off their EV1 model available, GM didn't satisfactorily advance the vehicle so they were blamed for pandering to the desires of CARB (Californian Air Assets Board), yet just to in any case be permitted to sell any remaining earth wasteful vehicles, for example, that they created a harmless to the ecosystem vehicle simply because of the forced legitimate arrangements.

Buyers were not permitted to purchase EV1 vehicles, yet they could lease them for a decent period, and that implies that all vehicles must be gotten back to GM toward the finish of the rent term, without the choice of procurement. After open fights of a gathering of GM's EV1 drivers fomented as a result of the difficulty of purchasing their vehicles, GM moved the whole armada of electric vehicles to a far off area and obliterated them! A gathering of activists recorded the entire activity, and it is completely archived in the film "Who Killed the Electric Vehicle?”

Figure 2.14: 15th of March 2005, the last EV1 was destroyed

Source: Pictures from documentary film: "Who killed the electric car?"

Rather than empowering shoppers to purchase EV1, GM chose to advance Hummer and persuade individuals that this is what they truly need and need. They additionally campaigned for state tax cuts going from $ 25,000 to an astounding $ 100,000 for every vehicle (or rather a smaller than usual tank) which is the greatest "oil customer" and furthermore the biggest vehicle out and about gauging 3 tons! (The most extreme tax breaks in 2002 for an electric vehicle added up to $ 4,000, and for a vehicle of 3 tons in 2003 $ 100,000!)

Practically all makers pulled out their electric vehicles from the market. Toyota offered its keep going RAV4-EVS on 22nd November 2002. Nonetheless, they kept on supporting a few many their clients and clients of Toyota RAV4-EV. EV1 can now just be found in two historical centers where they are uncovered without motors.

One of the ends made in the narrative "Who Killed the Electric Vehicle?" was that similarly as it was important to pass the law on wearing safety belts, putting airbags in vehicles, impetuses, and so forth, so the "perfect vehicles" are excessively significant for the "spotless climate" to be passed on to the car business to settle on their destiny.

The energy emergency of 2000 got restored interest mixture and electric vehicles. In light of the absence of huge makers for the creation of electric vehicles, a great deal of little organizations began to plan and publicize electric vehicles to people in general. In 1994, REVA Electric Vehicle Organization was set up in Bangalore - India, as an endeavor of the Maini working closely together Gathering India and AEV of California. In numerous nations REVA doesn't satisfy the states of an engine vehicle qualified to drive on interstates, and it is sorted in different classes, for example, in the USA the alleged Area electric vehicles (NEV) and weighty quadricycles in Europe. Until Walk 2011, REVA sold in excess of 4,000 vehicles all over the planet and it is accessible in 26 nations.

Pike Exploration gauge that in 2011 there were just about 479 000 NEV vehicles on the planet. The top selling NEVs are Worldwide Electric motorcars (Pearl) vehicles, with in excess of 45,000 vehicles sold as at December 2010. The development of the Think City all-electric vehicle, with a greatest speed of 110 km/h and a scope of 160 km, was sent off in 2008 by the Norwegian maker Think Worldwide, however because of monetary troubles the creation was ended. North of 1000 Think vehicles were sold in a few European nations and the USA. In June 2011, the organization defaulted on some loans and the creation was ended. The new proprietor planned to restart the creation in mid-2012 with a somewhat adjusted idea of Think City.

Figure 2.15:Think City

Source: http://en.wikipedia.org/wiki/Think_City

Californian producer of electric vehicles, Tesla Engines, 2004 began the improvement of the Tesla Roadster model, which was first conveyed to clients in 2008. Tesla Roadster is the principal electric vehicle adjusted for American interstates and accessible in sequential creation in the USA. From 2008 to December 2011, a larger number of than 2,100 vehicles were sold in 31 nations. Tesla was likewise quick to present lithium-particle batteries in its vehicle creation, and Roadster is the principal vehicle that has a reach more prominent than 320 km on a solitary charge and can arrive at a speed of north of 200 km/h.

Figure 2.16:Tesla Roadster

Source: www.teslamotors.com

In June 2012, the organization Tesla Engines started conveying Tesla S model (vehicle). This model saved the organization, which was very nearly breakdown. Not at all like Roadster, which is an energetic two-seater, is Model S an extravagant vehicle for the entire family. The essential cost of the Model S in the US market is around 60 thousand dollars, and this year they intend to convey 5,000 vehicles.

The fundamental model accompanies batteries that permit a scope of as much as 258 kilometers, however Tesla Engines likewise offers batteries of more noteworthy limit that permit this model to have a scope of up to 370 and surprisingly as much as 483 kilometers.

Tesla Superchargers are quick charging stations put on traffic courses in North America. As of now, just six stations are dynamic, yet the arrangement is to have around 100 of them by 2015. They are intended to fill about portion of the battery limit in thirty minutes. This is extra 240 kilometers. These quick charging stations are situated where you would somehow or another need to stop: close to cafés, bistros, and retail plazas. In many spots, sun oriented cells are placed on the top of the charging stations so the power is delivered from environmentally friendly power sources.

Figure 2.17:Tesla Superchargers

Figure 2.18: Tesla Model S

Source: www.teslamotors.com

Figure 2.19:Tesla Model X

Source: www.teslamotors.com

Mitsubishi I-MiEV was sent off in July 2009 for armadas of clients in Japan, and for different buyers in April 2010, trailed by deals in Hong Kong and Australia through a renting model. IMiEV was sent off in Europe in December 2010, including similar renditions under different brands Peugeot Particle and Citroën C-Zero.

2.4 Electric Vehicle Technology

Electric vehicles (EVs) utilize a bunch of batteries to store the electrical energy that controls the engine. The batteries are charged by connecting the vehicle to a power source in a charging station. The electric engine acts as a generator during slowing down which charges the batteries.

2.4.1 Working principle of Electric Vehicles

Electric vehicles (EVs) have an electric engine rather than a gas-powered motor. The electric engine is fueled by a huge footing battery pack and connected to a charging station to charge [7]. It runs on power, subsequently, the vehicle radiates no exhaust from a tailpipe and doesn't contain the average fluid fuel parts, for example, a fuel siphon, fuel line, or gas tank.

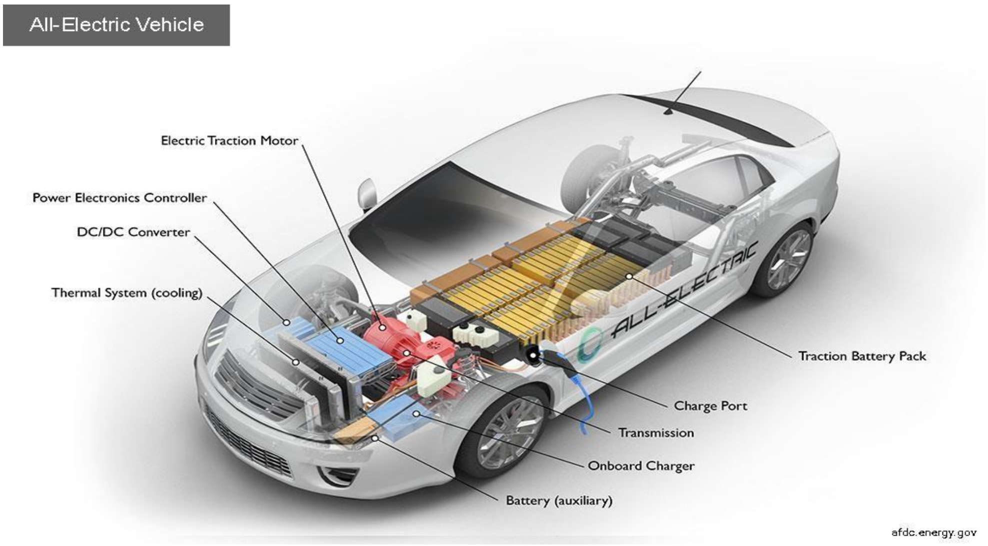


Figure 2.20: All-Electric Vehicles [7]

2.4.2 Key Components of an Electric Vehicles

The parts of the electric vehicle are displayed in Figure 2.19.

Battery: The batteries give power to control vehicle extras in electric drive vehicles.

Charge Port: The charge port interfaces the vehicles to an outside power supply to charge the battery pack.

DC/DC Converter: It changes over higher-voltage DC power from the footing battery pack to the lower-voltage DC power expected to run vehicle extras and re-energize the assistant battery.

Electric Footing Engine: It drives the vehicle's wheels utilizing power from the foothold battery pack. The engine some of the time goes about as a generator during slowing down.

On-Board Charger: It takes the air conditioner power through the charge port and converts it to DC ability to charge the foothold battery. Battery qualities like voltage, current, temperature, and condition of charge while charging the pack are checked.

Power Hardware Regulator: It deals with the electrical energy stream, controls the speed of the electric engine and the force it produces.

Warm Framework: This framework keeps an appropriate working temperature scope of the motor, electric engine, power gadgets, and different parts.

Transmission: The transmission moves mechanical power from the electric power source to drive the wheels of the electric vehicles.

2.5 Batteries of EVs

Hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and all-electric vehicles all rely on energy storage systems like batteries (EVs). Lithium-ion batteries have become the most widely used batteries in portable consumer devices such as cell phones and laptops due to their high energy per unit mass, high power-to-weight ratio, high energy efficiency, good temperature performance, and low self-discharge features. This battery is recyclable, but the cost of recovery is extremely high, making it a difficult task for the business. Other choices include nickel-metal hydride and lead-acid batteries, but they are less effective than lithium-ion and their availability is dwindling.

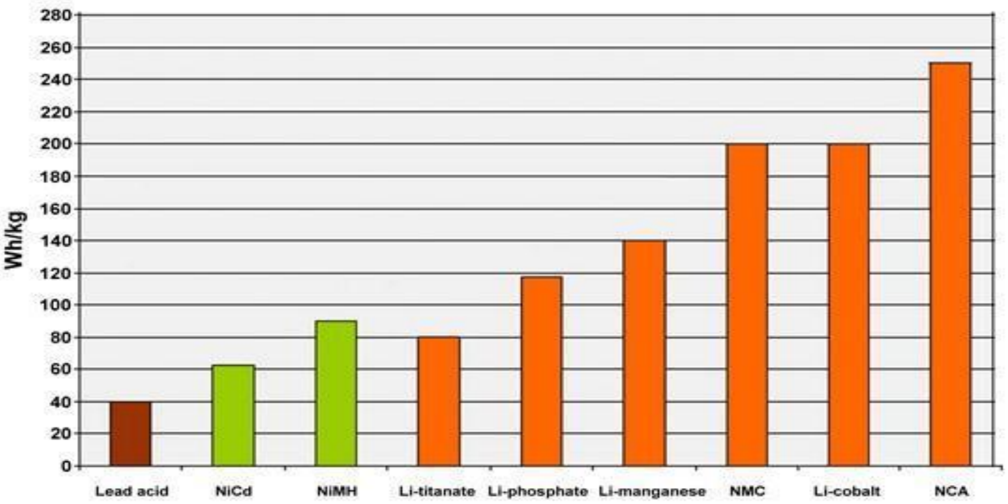


Figure 2.21: Comparison of Batteries [8]

The batteries used in electric vehicles are not the same as those used in electrical devices. They must have a large storage capacity while remaining compact and light in weight, as well as be reasonably priced. In electric vehicles, there are several distinct types of batteries. Sodium Sulfur (NAS), flow batteries, lithium polymers, lithium-ion batteries (Li-ion), and nickel metal hybrids are among examples (NiMH). Because of their lightweight and superior efficiency as well as energy capacity, the last two are commonly employed in all available electric vehicles. They also deliver the highest acceleration and driving distance performance for electric vehicles.

2.5.1 Battery Technologies Used in Electric Vehicles

Various battery technologies with varying nominal voltages and energy densities are now available and being developed. Table 1.1 [3] lists battery technologies and attributes that are routinely utilized in electric vehicles and are still being researched.

Battery Types	Nominal Voltage (V)	Energy (Wh / kg)	Cycle Life	Memory Effect	Operating Temperature (°C)
Pb-acid	2		1000	No	-15, +50
NiCd	1.2	50-80	2000	Yes	-20, +50
NiMH	1.2	70-95	<3000	Rarely	-20, +60
Zebra	26	90-120	>l200	No	+245, +350
Li-ion	3.6	118-250	2000	No	-20, +60
LiPo	3.7	130-225	>l200	No	-20,+60
Zn-air	1.65	460	200	No	-10, +55
Li-S	2.5	350-650	300	No	-60,+60
Li-air	29	1300-2000	100	No	-10, +70

Table 2.1 Battery Technologies Used in Electric Vehicles

2.5.2 Lead-Acid (Pb-Acid) Battery

Lead-corrosive batteries are an old-type battery innovation that is often utilized in numerous applications. Batteries comprise of primarily certain, negative terminals and electrolyte liquids. In this kind of battery, lead is utilized in the negative terminal, lead dioxide is utilized in the positive anode (PbO2) and sulfuric corrosive (H2SO4) is utilized as electrolyte fluid. The primary benefits of lead-corrosive batteries are their affordability, high release current, and no memory impact. Notwithstanding these benefits, it has a few disservices. The principle disservice is that battery duration is diminished when not being used. Moreover, low result voltage and low energy thickness are a portion of different hindrances.

2.5.3 Nickel Cadmium (NiCd) Battery

Nickel-cadmium batteries are a protected and modest innovation. Nickel-cadmium batteries use cadmium/cadmium hydroxide ($Cd/Cd(OH)2$) on the contrarily charged terminal, nickel hydroxide/nickel bull hydroxide ($Ni(OH)2/NiOOH$) on the decidedly charged anode, and potassium hydroxide (KOH) materials as the electrolyte. NiCad batteries can be energized to multiple times. In any case, the batteries should be completely released prior to charging. At the point when the battery is charged before it is completely released, the charge limit drops and this will abbreviate the existence of the battery. This is known as a memory impact. This battery, which gives a high release current, has a higher energy thickness than lead-corrosive batteries. In any case, this battery innovation has critical burdens. These are high release current worth, low charging proficiency, and awful memory impact.

2.5.4 Nickel Metal Hydride (NiMH) Battery

Ni-MH batteries contain a wide range of mixtures like titanium, nickel, manganese, cobalt, aluminum, vanadium, zirconium, iron, and chromium. These batteries are strong and can be re-energized more than once. Ni-MH batteries produce 1.2V potential in a battery unit. Ni-MH batteries have high energy limits. Like Ni-Miscreant batteries, Ni-MH batteries ought not to be completely energized without releasing, as the memory impact likewise applies to these batteries. In spite of the fact that Ni-MH batteries appear to be invaluable in many regards, the main downside is that the release times are very short when not being used.

2.5.5 Lithium Ion (Li-ion) Battery

Lithium metal oxides are utilized as sure cathodes in lithium-particle batteries with the benefit of low harmfulness, high limit, and inexpensiveness contrasted with different materials. Ordinarily utilized oxides: Lithium cobalt oxide ($LiCoO2$), Lithium nickel oxide ($LiNiO2$), Lithium manganese oxide ($LiMn2O2$). Lithium-particle battery innovation has unexpected attributes in comparison to nickel-based battery innovation. It has a higher ostensible voltage and higher energy thickness than nickel-based battery packs.

2.5.6 Lithium Ion Polymer (LiPo) Battery

Lithium-particle batteries have practically similar attributes. The main distinction between them is the utilization of polymer material as electrolyte in lithium-particle polymer batteries. The electrical conductivity of polymer electrolyte material is higher than other natural fluid electrolytes. Also, the utilization of this material permits lithium polymer batteries to be created all the more effectively, quicker, and with various shapes.

2.5.7 State of Charge (SoC)&Depth of Discharge (DoD)

It is determined as the percentage of the battery's current capacity to the maximum amount of charge that it can hold. It's a battery pack's equivalent of a fuel gauge in a charged electric car. SoC is measured in percentage points, with 0 percent equaling empty and 100 percent equaling filled. When the DoD is 0 percent, the SoC is 100 percent, and when the DoD is 100 percent, the SoC is 0 percent. It's most commonly used when talking about the present state of a battery [9]. Figure 2.21 depicts the SoC and DoD concepts.

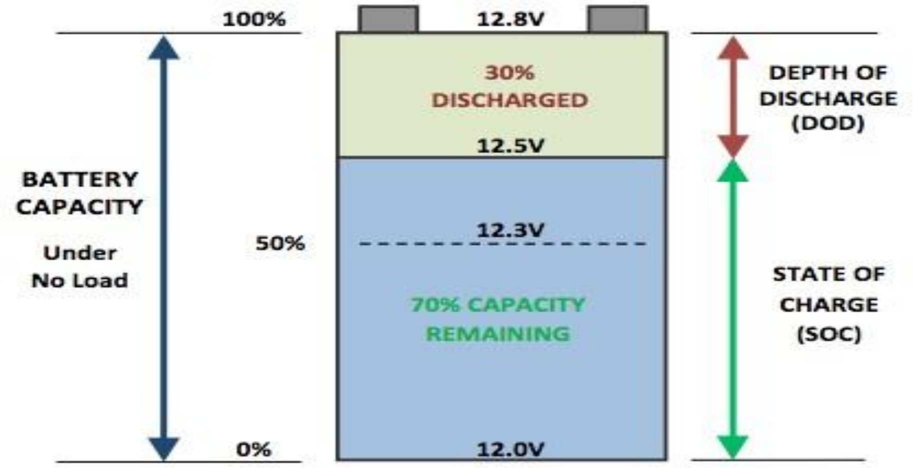


Figure 2.22: SoC&DoD [10]

The Department of Defense (DoD) is the SoC's counterpart. It determines how drained the battery is in comparison to a full discharge, when the battery has used up all of its energy capacity. It's measured as a percentage of the battery's total capacity. The Depth of Discharge, or DoD, of a battery is 100 percent when it has discharged its complete energy capacity. The battery's DoD is 0 percent when completely charged. For example, if you have a 100 amp hour battery and consume 50 amp hours, the battery has been depleted 50%, indicating a 50% depth of discharge [11].

2.6 AC Motor Drive History

AC drives are AC engine speed control frameworks. A slip-controlled injury rotor enlistment engine (WRIM) drive controls speed by differing engine slip by means of rotor slip rings either by electronically recuperating slip power took care of back to the stator transport or by shifting the opposition of outer resistors in the rotor circuit. Alongside swirl current drives, opposition based WRIM drives have lost prevalence since they are less productive than AC/DC-AC-based WRIM drives and are utilized uniquely in extraordinary circumstances.

Slip energy recuperation frameworks return energy to the WRIM's stator transport, changing over slip energy and taking care of it back to the stator supply. Such recuperated energy would some way or another be squandered as hotness in obstruction based WRIM drives. Slip energy recuperation variable-speed drives are utilized in such applications as enormous siphons and fans, wind turbines, shipboard impetus frameworks, huge hydro-siphons/generators, and utility energy stockpiling flywheels. Early slip energy recuperation frameworks involving electromechanical parts for AC/DC-AC change. As a rule, a VFD in its most fundamental design controls the speed of acceptance or simultaneous engine by changing the recurrence of the power provided to the engine.

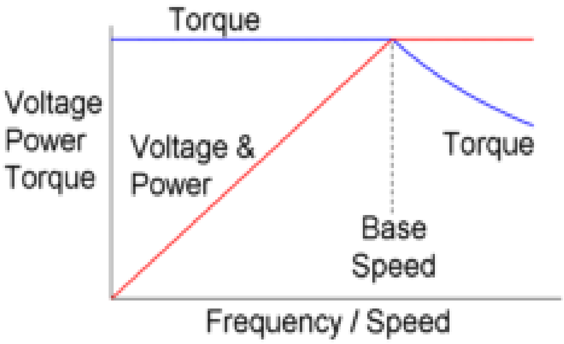


Figure 2.23: Frequency of AC Motor Drive

While changing VFD recurrence in standard low-execution variable-force applications utilizing Volt-per-Hertz (V/Hz) control, the air conditioner engine's voltage-to-recurrence proportion can be kept up with consistent, and its power can be shifted, between the base and most extreme working frequencies up to a base recurrence. Steady voltage activity above base recurrence, and thusly with diminished V/Hz proportion, gives decreased force and consistent power capacity.

Regenerative AC drives are a kind of AC drive which have the ability to recuperate the slowing down energy of a heap moving quicker than the engine speed (a redesigning burden) and return it to the power framework. The VFD article gives extra data on electronic speed controls utilized with different sorts of AC engines.

2.7 Review of Related Works

Despite the fact that innovative work on electric vehicles show themselves in the twentieth century, the underlying beginning depends on the eighteenth century [1]. The main electric vehicle was created by Robert Anderson somewhere in the range of 1832 and 1839 as a traveler vehicle. Christopher Becker who was the colleague of Teacher Stratingh produced the main electric vehicle created by Educator Stratingh in 1835. In 1842, Thomas Davenport and Robert Davidson fostered the principal electric vehicle that couldn't be re-energized. Gaston Plante and Camille Faure then, at that point, fostered a battery-powered battery to be utilized in electric vehicles rather than non-battery-powered batteries [23].

Lately, the pattern towards electric vehicles has expanded impressively all through the world, and concentrates in this space have expanded. The primary purposes behind this propensity are to intend to decrease ecological contamination and to expand productivity. Therefore, interests in electric vehicle innovation are expanding step by step. A large portion of these ventures are made for battery innovation which is an imperative piece of electric vehicles. The distance that electric vehicles can travel relies straightforwardly upon the energy put away in the battery. The work in the battery field proceeds in many branches and many examinations are being done on various battery types. The fundamental battery advances normally utilized in electric vehicles are; (Lead-corrosive) [24], NiCd (Nickel Cadmium) [25], NiMH (Nickel Metal Hydrate) [26], and Li-particle (Lithium Particle) batteries. Li-particle type batteries are more liked for electric vehicles. This is mostly because of the great result voltage, the high energy thickness that can be put away, and the more drawn out help life contrasted with other battery types. Notwithstanding, they actually don't have the ideal valuable life [27, 10].

At the point when the qualities of the batteries are analyzed, it is seen that their administration life is straightforwardly connected with the charging system and use. Charging is the main element influencing the utilization of batteries. Contingent upon the charging strategy and shape, the existence of the battery cells can be diminished or expanded for longer periods near full limit. Uncontrolled charging of batteries might bring about genuine harm, like the blast of batteries, and deadly occasions. Hence, battery the board frameworks should be utilized to control and charge the batteries in a controlled way [11, 28].

The battery the executive's framework is the unit wherein the batteries are assessed and overseen by utilizing the battery charge rate [29]. The BMS plays out a few assignments like estimating the framework voltage, current, and temperature, the phone's condition of charge (SoC), deciding the condition of wellbeing (SoH), and observing and putting away estimated information. The BMS's most significant undertaking is cell adjusting and it can influence the battery wellbeing and effectiveness contrarily.

In this field, heaps of studies were performed and various techniques applied battery cells to diminish the adjusting impact on the framework [1-29]. The cell adjusting techniques can be isolated into two fundamental themes as detached and dynamic adjusting [8]. Resistive, capacitive, and inductive parts use for dynamic and detached charge adjusting frameworks [8]. The resistive technique is called inactive, capacitive, and inductive strategies are called dynamic charge adjusting frameworks. Additionally, dynamic adjusting frameworks incorporate a converter and transformer-based adjusting procedures.

In the writing, uninvolved adjusting based techniques can be applied in two distinct ways. One of these techniques is the proper shunt opposition strategy and the adjusting system is performed persistently [5]. In this technique, a resistor is associated with every battery cell. The adjusting current shifts as indicated by the worth of this obstruction. In [5] was introduced, examined, and assessed the various strategies proposed to accomplish individual cell balance for series battery stacks.

The subsequent technique depends on controlling the adjusting opposition. This technique is alluded to as controlled shunt obstruction [7]. Semiconductor-based exchanging components or precisely exchanging transfers can be utilized for this control procedure. The overabundance energy of the battery cell is enjoyed on this obstruction with this strategy. In [7], one of the inactive adjusting strategies, a controlled shunt resistor strategy was utilized. In this framework, exchanging activities are completed by involving transfers for control tasks. Because of utilizing this strategy, higher effectiveness is acquired contrasted with different frameworks. Simultaneously, the adjusting system was performed quicker than in various frameworks. Various examinations have been directed on Li-Particle batteries including adjusting strategies. In these investigations, different control chips and programming applications are utilized for adjusting control [30].

Dynamic adjusting techniques utilize outside circuits to effectively move the energy among cells to adjust them. Dynamic adjusting strategies can be separated into three primary subjects. It very well may be gathered as a capacitor, inductor-change, or converter based [8]. In [9-10] capacitor-based adjusting techniques are outlined. It was communicated that the control methodology was straightforward and didn't require astute control. Since these frameworks were had just two states. The planned framework could work in both re-energizing and releasing tasks. Also this framework impediment was a generally long leveling time.

In [13], utilized one inductor to move energy between the entire pack. Initially the control framework detected the voltage of the cells and chose different cells as indicated by the charge conditions. In [12, 14], the multi-inductor framework was utilized for the adjusting framework. This strategy utilizes an n-1 inductor for adjusting n cells. PWM signal was involved exchanging for adjusting framework and complex control was required. It is resolved that the evening out season of the framework is excessively long.

In [15-16], a solitary windings transformer technique was utilized. The applied strategy for these review's not entirely settled as quick adjustment speed and low attractive misfortunes yet hindrances were seen as control of the framework was troublesome and framework execution was costly.

Energy converters can be utilized for dynamic cell adjusting techniques. A buck-support converter strategy was proposed in [14]. Here, every one of the cells were associated in corresponding with a converter. This strategy can firmly adjust every one of the cells on a charge cycle. The outcome of this strategy shows that adjusting has amazing spreading and insignificant circuit misfortunes contrasted with different techniques.

Essentially, in [31] a disengaged DC-DC converter with a multi connecting transformer was utilized in charging and charge balance capacities. In [32], a two-way DC-DC converter was utilized to adjust the phones during both charging and releasing. It is easy to assemble this circuit, however a few electrical parts needed in the circuit increment the complete expense of the framework.

The Full-span PWM converter-based method was proposed in [33]. These sorts of converters can be utilized as AC/DC or DC/DC converters. The topological design of the circuit is appropriate for this reason. In such an application, the energy in the battery pack can be moved to the feeble cell. The fundamental benefits of this circuit geography are its high productivity and appropriate for high power applications. The main disadvantage is the trouble and intricacy of the control stage

2.8Challenges

Presently, EVs face various difficulties which are the disallowing factors for mass sending and commercialization. High introductory expenses, restricted lifetime, and somewhat lackluster showing at low temperature are regularly referred to as the main issues, with the last three straightforwardly including the ESS and BMS of the vehicle [12-15]. The normal lifetime of batteries (commonly characterized by a 20% corruption in battery limit) in EVs is around 8 to 10 years [13]. Practically speaking, the lifetime of the battery is diminished because of the powerful profile of the vehicle during speed increase and slowing down, which can be significantly more than 10× higher than the normal power. The EV invests a considerable lot of energy in low power and inactive modes, be that as it may, it encounters a few high power tops as often as possible. Driving conduct, re-energizing propensities, profundity of release (DOD), and surrounding temperature are different variables that sway the lifetime of the batteries by shifting degrees. Dissecting the impacts of these elements can work on the capacity of battery models in both execution and lifetime forecast [13, 16]. In this undertaking, a stage is planned and carried out to investigate the impacts of normal release current, surrounding temperature, and drive cycle elements. Before talking about the previously mentioned stage and its investigation, it is fundamental to have an outline of batteries, normal EV battery sciences, and their related difficulties.

CHAPTER 3

RESEARCH METHODOLOGYAND CALCULATION

3.1 Introduction

This method can be used to charge electric vehicles (EVs) using EV charging systems. We chose a high-voltage, high-energy density Li-ion battery for the on-board rechargeable battery to reduce vehicle weight while maintaining the requisite cruising range while developing commuter-use EVs.

3.2 EVs Charging Methodology

The block diagram of the system design used in this model is shown in Figure 3.1. A wireless power transmission system's transmitter and receiver are the two most important components. It necessitates an input power source, which can be either AC or DC.

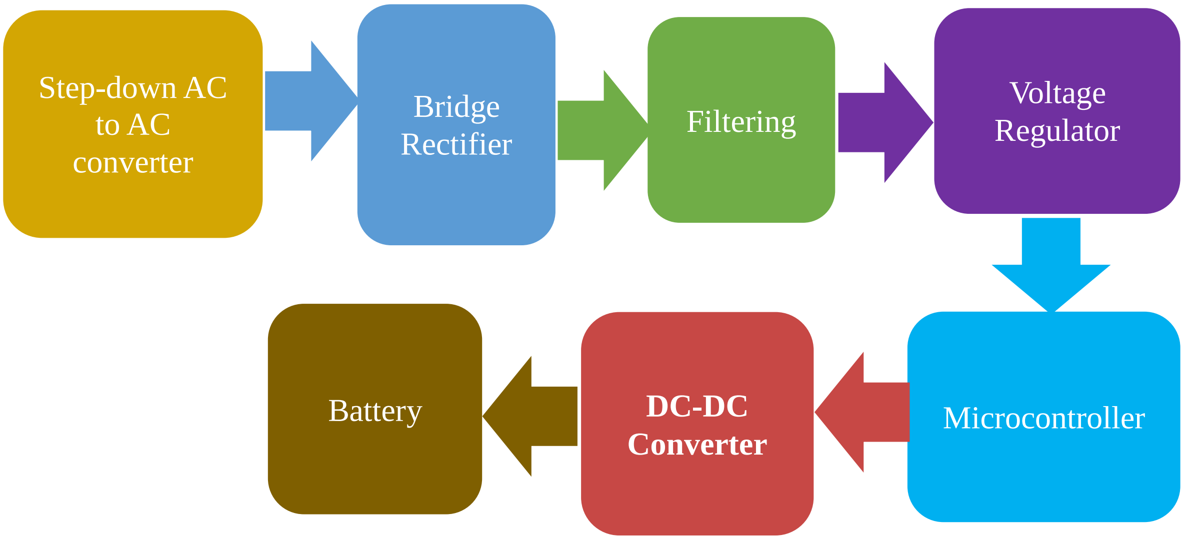


Figure 3.1: Block Diagram of EVs Battery Charging Methodology

3.2.1 Step-down AC to AC converter

If a power supply using mains /line supplies of 220 volts AC is used, then the input usually has a transformer to transform the incoming line voltage to required level for the power supply.

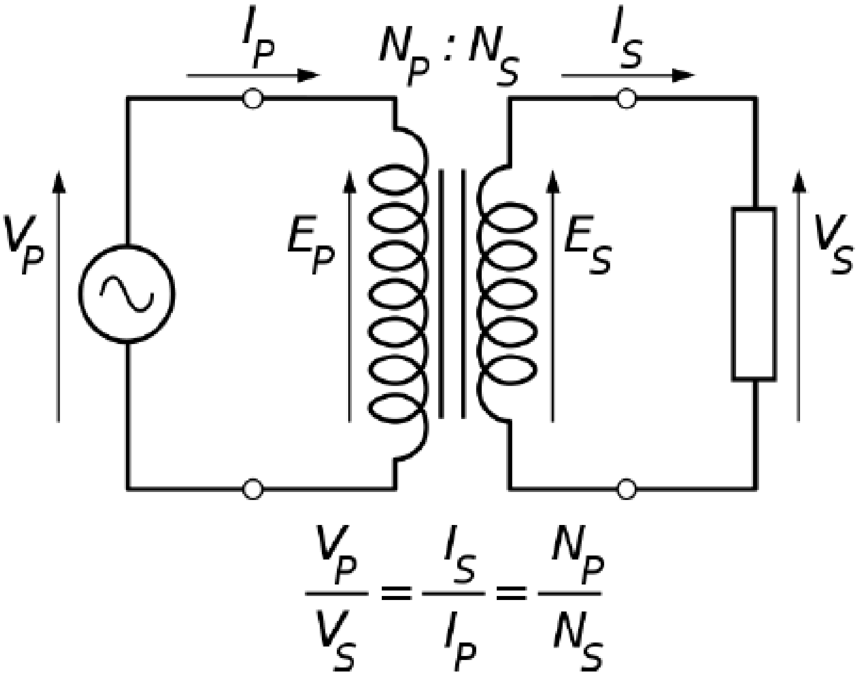


Figure 3.2: Transformer

Calculation:

1. Primary Inductance
2. secondary Inductance
3. coupling factor
4. primary DC resistance
5. Secondary DC resistance

∴ Vp = Voltage on the primary coil = 220v (r.m.s = root mean square)

∴ Vs = Voltage on the secondary coil = 12v (r.m.s)

CP = coupling factor = 1

Let,

∴ Lp = primary coil inductance = 4H

So, Ls = secondary coil inductance =?

∴ Peak voltage = r.m.s × √2

$$\therefore \frac{Vs}{Vp} = CP \times \sqrt{\frac{Ls}{Lp}}$$

Finding Ls,

Making Ls the subject of the formula,

$Ls = \frac{\mathrm{Vs\,2 \times Lp}}{\mathrm{CP\,2\ \times Vp\,2}}$ -------------- (2)

$Ls = \frac{144\ \times 4}{48400} = 0.0119$

∴Ls = 0.0119H

Finding primary DC resistance and secondary DC resistance

Primary DC resistance = Rp

Secondary DC resistance = Rs

$V= IR$ ------------ (3)

$R= \frac{V}{I}$ ------------- (4)

$Rp = \frac{Vp}{Ip}$ --------- (5)

Vp = 220V, We assume Ip = 1A

$Rp = \frac{220}{1} = 220V$

To find the current on the secondary coil, we use the Transformer formula

$\frac{Vp}{Vs} = \frac{Is}{Ip}$ $------(6)$

Vp = 220V

Vs = 12V

Ip = 1A

Is =?

Therefore,

$Is = \frac{Vp \times Ip}{Vs}$ ------------ (7)

$Is = \frac{220 \times 1}{12} = 18.33A$

Hence,

$Rs = \frac{Vs}{Is}$ ----------------- (8)

$Rs = \frac{12}{18.33} = 0.6557$

1. Primary Inductance = 4H
2. Secondary Inductance = 0.0119H
3. Coupling factor = 1.0
4. Primary DC resistance = 220 ohm
5. Secondary DC resistance = 0.6557 ohm

Amplitude = peak voltage = r.m.s × √2 = 220V × √2 = 311.1V

Frequency = 50Hz

3.2.2 Bridge Rectifier

Bridge Rectifiers utilize four diodes that are organized astutely to change over the air conditioner supply voltage to a DC supply voltage. The Air conditioner signal is applied at the info terminals a and b, and the result is seen across the heap resistor R1.

In the main certain half pattern of the air conditioner signal, the diodes D2 and D3 become forward one-sided and begin leading. Simultaneously, the diodes D1 and D4 will be converse one-sided and won't lead. The current will course through the heap resistor by means of the two forward-one-sided diodes. The voltage seen at the result will be positive at terminal d and negative at terminal c.

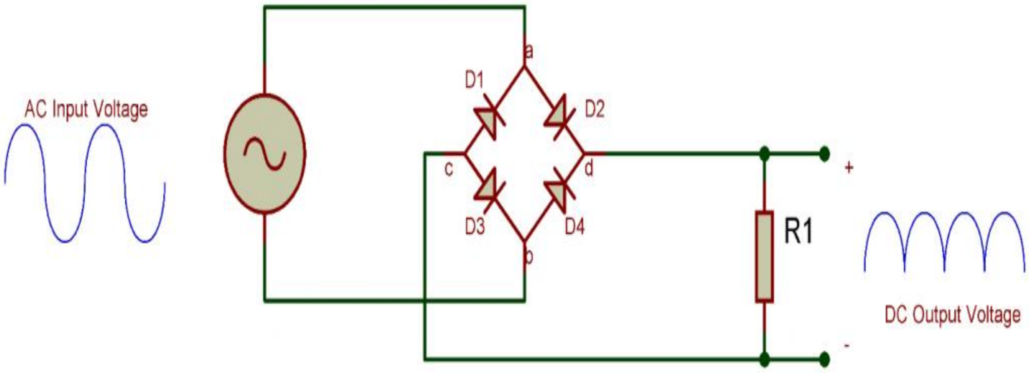


Figure 3.3: Bridge Rectifier

Presently, during the negative half pattern of the air conditioner signal, the diodes D1 and D4 will be forward one-sided and diodes D2 and D3 will become opposite one-sided. The positive voltage will show up on the anode of D4, and the negative voltage will be applied to the cathode of D1.

It is quite important now that the current that will be coursing through the heap resistor will have a similar heading as it has with the positive half cycle. Subsequently, regardless of the extremity of the information signal, the result extremity will forever be something similar. We can likewise say that the negative half pattern of the air conditioner signal has been altered and is showing up as a positive voltage at the result.

3.2.3 Filtering

The capacitor works like a high pass channel that permits high frequencies and squares direct current. Likewise, they can likewise fill in as a low pass channel to permit DC and square AC. Since a capacitor gives incredibly low obstruction for high-recurrence flags, these signs will supply through the capacitor.

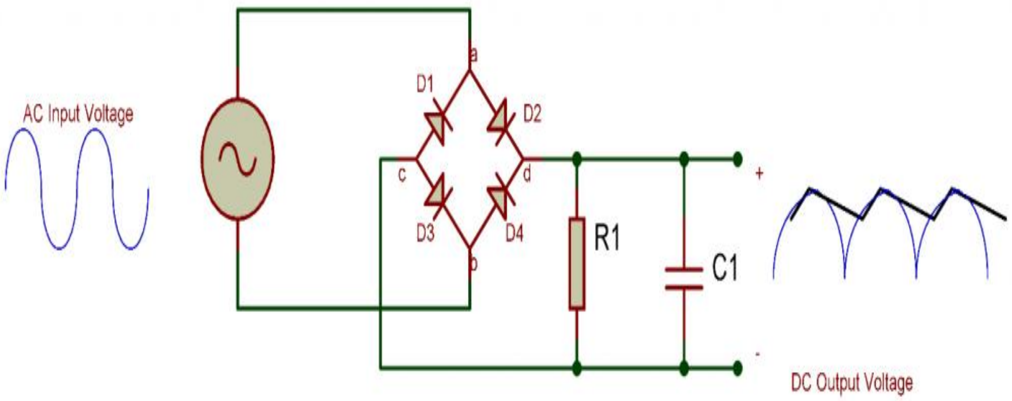


Figure 3.4: Filtering

Like this, the circuit in this game plan is a high-recurrence channel. The signs like low-recurrence current won't supply all through the capacitor, as it gives high opposition for low-recurrence signals. For low-recurrence flags, the capacitor offers very high opposition and for high-recurrence signals, it demonstrates less obstruction. So it goes about as a high pass channel to permit high-recurrence signals and square low-recurrence signals.

3.2.4Voltage Regulator

A voltage controller or regulator is a framework intended to naturally keep a consistent voltage level. Contingent upon the plan, it very well might be utilized to control at least one AC or DC voltages. A 3-pin direct voltage controller like the LM7815 gives a predictable, 15 volt 1 amp yield inasmuch as the information voltage doesn't surpass 36 volts. The last two digits of 7815 show the result voltage that is voltage. The voltage controller goes about as a voltage divider on the circuit. The activity of a straight controller is totally simple.

- The last two digits of 7815 indicate the output voltage that is voltage.
- The voltage regulator acts as a voltage divider on the circuit.
- The operation of a linear regulator is completely analog.

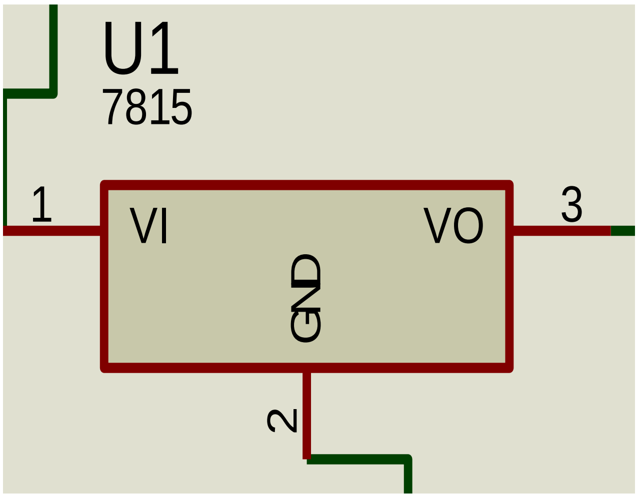


Figure 3.5: Voltage Regulator

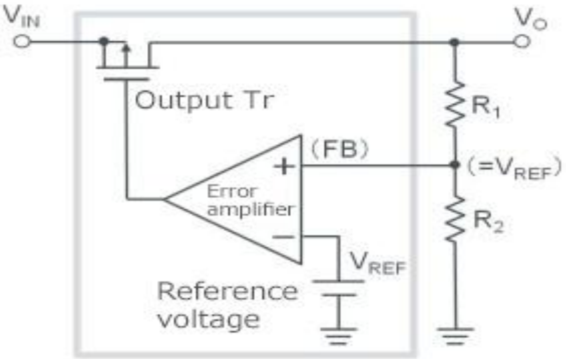


Figure 3.6: Reference Voltage

- It uses an operational amplifier in a feedback loop circuit, which is one of the most fundamental control circuits.
- The error amplifier continuously monitors and compares the feedback voltage from the regulator output with the reference voltage, regulates the power transistor so that the difference is zero, and maintains the VO value constant, even when the input or load fluctuates and the output voltage begins to change. This is a feedback loop-controlled regulation.

$$V_O = \frac{V_{REF}}{R_2} \times (R_1 + R_2) = \frac{R_1 + R_2}{R_2} \times V_{REF}$$

3.2.5 Microcontroller

- For high MOSFET switching speed, an Arduino Uno is employed as a pulse generator. It sends clock pulses to the MOSFET's base. These clock pulses have a frequency of around 980.39 Hz. MOSFETs switch very quickly as a result of this.

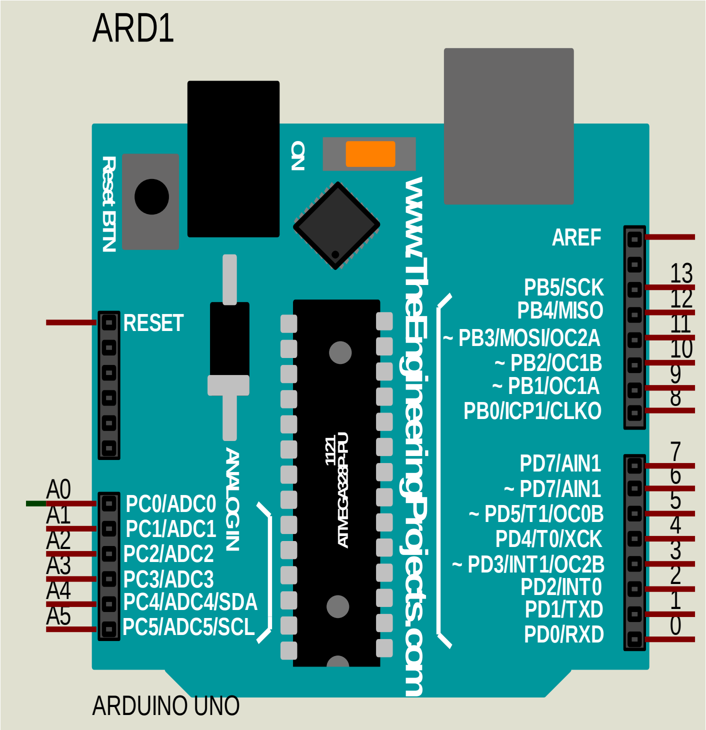


Figure 3.7: Microcontroller: Arduino UNO

- Because the potentiometer provides an analog value to Arduino, the pwm voltage received by the gate terminal of the MOSFET from PWM pin 5 of Arduino is determined.
- The output voltage across load is ultimately controlled by this parameter.

3.2.6 DC-DC Converter

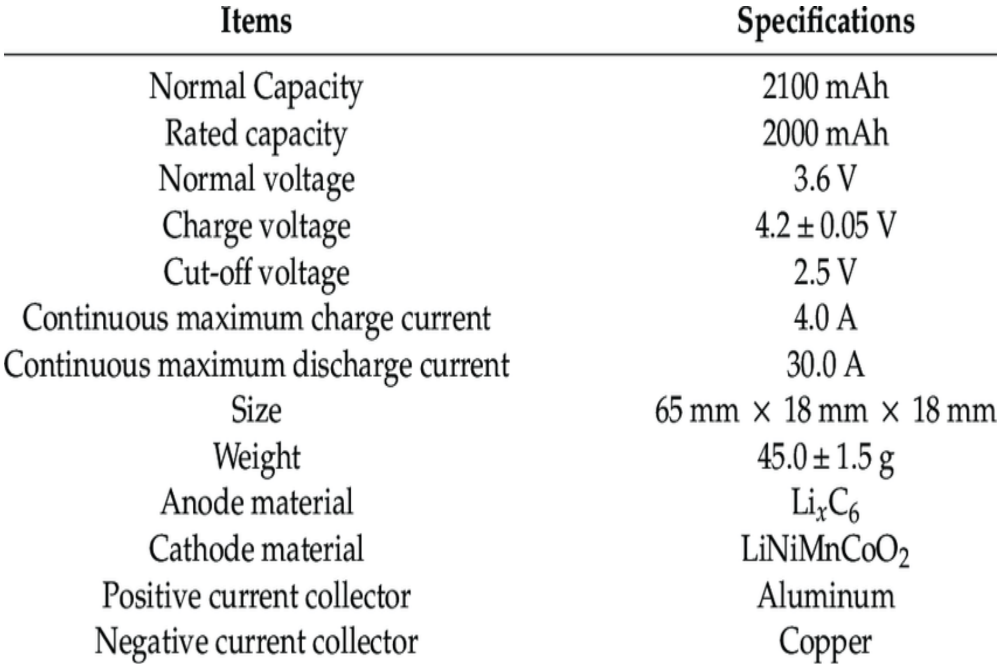
Arduino Uno sends clock pulses to base of MOSFET

- Mosfet is used for two purposes:
  - ➢ For high speed switching of the output voltage.
  - ➢ To provide high current with less dissipation of heat.
- When it switches off this stored energy is released to the loadWhen mosfet is on inductor stores energy and.
- If this circuit is run without connecting an inductor, then there are high chances of damaging the mosfet due to high voltage spikes on terminal of mosfet.

- To prevent mosfet from these high voltage spikes it is connected.
- Apart from this, schottky diode dissipates very low heat and work fine at higher frequency than regular diodes. Schottky diode completes the loop of current when mosfet is switched off and thus ensuring smooth supply of current to load.

3.2.7 Battery

A lithium-ion (Li-ion) battery is an advanced battery technology that uses lithium ions as a key component of its electrochemistry.



Items	Specifications
Normal Capacity	2100 mAh
Rated capacity	2000 mAh
Normal voltage	3.6 V
Charge voltage	4.2 ± 0.05 V
Cut-off voltage	2.5 V
Continuous maximum charge current	4.0 A
Continuous maximum discharge current	30.0 A
Size	65 mm × 18 mm × 18 mm
Weight	45.0 ± 1.5 g
Anode material	Li_xC_6
Cathode material	$LiNiMnCoO_2$
Positive current collector	Aluminum
Negative current collector	Copper

Figure 3.8: lithium-ion (Li-ion) battery

3.2.7.a Li-ion Battery Charging Considerations (Trickle Charger)

- The continuous trickle charger is the most basic sort of battery charger. It applies a steady voltage and current to the battery to charge it at its self-discharge rate, regardless of whether the battery is fully charged.
- To avoid overcharging the battery, a simple trickle charger must be manually shut off after a period of time.
- If the battery charge level is extremely low, it is charged at a decreased constant current rate of around 1/10 of the full-rate charging rate mentioned next.
- The battery voltage rises during this time, and when it reaches a certain level, the charge rate is boosted to the full charge rate.

3.2.7.b Proposed Float Charger For Li-Ion Battery Charging

- A trickle charger with an automatic on/off switch is the float charger. When the battery voltage hits a predefined reference level (VREF1), which corresponds to full charge or float charge, the charger detects it and turns off the current to the battery.

- The current to the battery is turned back on when the battery discharges to a second predetermined level (VREF2).

3.2.8 Lithium Battery Characteristic

Lithium-ion batteries are battery-powered batteries that utilize no watery electrolyte which were marketed in the mid-1990s. There are four parts in a lithium-particle cell: anode, cathode, separator, and no watery electrolyte. During the charging system, the lithium particles move from the cathode, through the electrolyte, to the anode, and afterward return during release. Lithium-particle battery cells are made as a heap of barrel shaped cells. In the primary setup, the cathode, anode, and separator are typified in an overlay film. In the subsequent one, the layers are rolled and fixed in a metal can.

Lithium-particle batteries have the attributes of high power thickness, long life, low self-release, low upkeep expenses, and low ecological effect. In any case, lithium has high reactivity, so there are specialized restrictions connected with the wellbeing of building batteries.

3.2.8.aCharging Characteristic For Li-Ion Battery

The full charge voltage of a 12V SLA battery is ostensibly around 13.1 and the full charge voltage of a 12.8V lithium battery is around 13.4. A battery will possibly support harm assuming the charging voltage applied is essentially higher than the full charge voltage of the battery.

This implies a SLA battery ought to be kept underneath 14.7V for Stage 2 charging and beneath 15.2V for lithium. Float charging is just needed for a SLA battery, suggested around 13.8V. In light of this, a charge voltage range somewhere in the range of 13.8V and 14.7V is adequate to charge any battery without causing harm. While choosing a charger for one or the other science, it is critical to pick one that will remain between the cutoffs points recorded previously.

"Chargers are chosen to match the limit of the battery to be charged since the current utilized during charging depends on the limit rating of the battery. A lithium battery can be charged as quickly as 1C, though a lead-corrosive battery ought to be kept beneath 0.3C. This implies a 1OAH lithium battery can ordinarily be charged at 1OA while a 1OAH lead-corrosive battery can be charged at 3A.

The charge remove current is 5% of the limit, so the end for the two batteries would be O.5A. Normally, the terminal current not entirely settled by the charger. All-inclusive chargers will regularly have a capacity to choose the science. This capacity picks the ideal voltage charging range and decides when the battery is completely energized. On the off chance that it is charging a lithium battery, the charger ought to stop naturally. Assuming it is charging a SLA battery, it should change to a float charge.

3.3 Starting System of Electrical Vehicle

A three-phase Induction Motor is Self-Starting. At the point when the inventory is associated with the stator of a three-stage acceptance engine, a turning attractive field is created, and the rotor starts pivoting and the enlistment engine turns over. At the hour of beginning, the engine slip is solidarity, and the beginning current is exceptionally enormous. The motivation behind a starter isn't to simply turn over the engine, however it fills the two principle roles.

They are as per the following:

- To diminish the weighty beginning current,

- To give over-burden and under-voltage insurance.

The three-stage acceptance engine might be begun by associating the engine straightforwardly to the full voltage of the inventory. The engine can likewise be begun by applying a diminished voltage to the engine. The force of the acceptance engine is relative to the square of the applied voltage. In this manner, more noteworthy force is applied by an engine when it is begun on full voltage than when it is begun the decreased voltage.

There are three primary strategies for Beginning of Enclosure Enlistment Engine. They are as per the following:

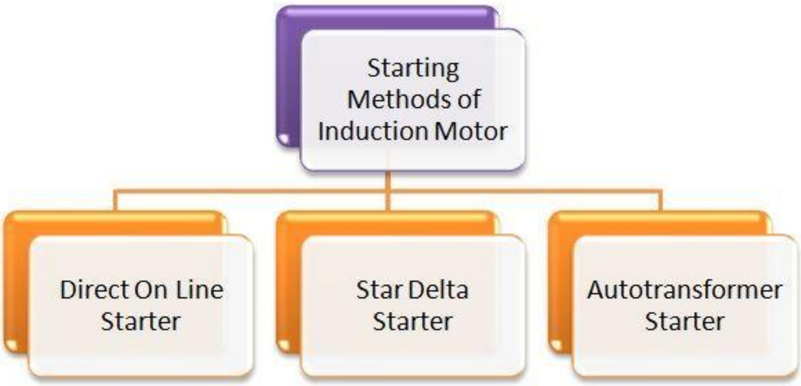


Figure 3.9: Starting method of Induction Motor

Direct on-line Starter

The direct web-based starter strategy, of an enlistment engine, is straightforward and conservative. In this technique, the starter is associated straightforwardly to the inventory voltage. By this technique, little engines up to 5 kW rating are begun to keep away from the stock voltage change.

Star delta Starter

The star-delta starter strategy for beginning three-stage acceptance engines is exceptionally normal and generally utilized among every one of the techniques. In this technique, the engine runs at delta-associated stator windings.

Autotransformer Starter

The Autotransformer is utilized in the two sorts of associations, i.e., either star associated or delta associated. The autotransformer is utilized to restrict the beginning current of the acceptance engine.

The over three starters are utilized for the enclosure rotor enlistment engine.

Slip Ring Acceptance Engine Starter Technique.

In the Slip Ring Enlistment Engine starter, the full inventory voltage is associated across the starter. The association graph of the slip ring starter acceptance engine is displayed beneath:

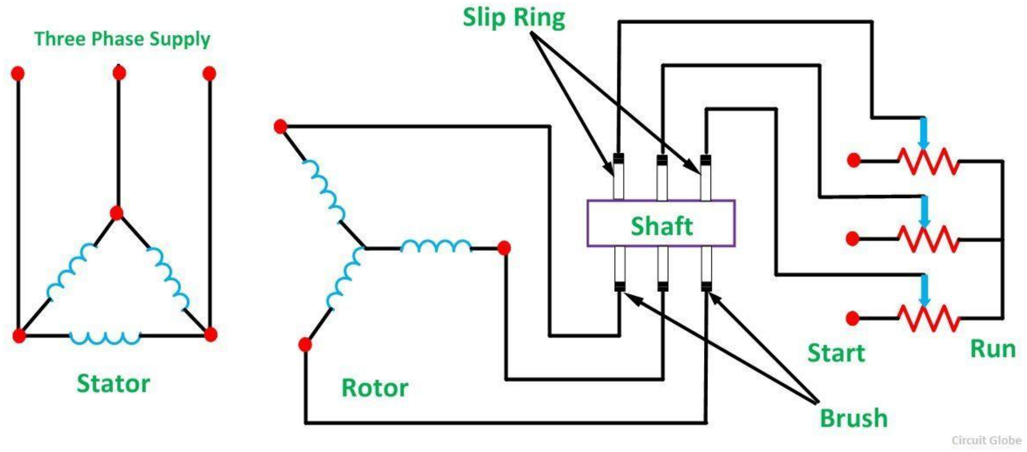


Figure 3.10: Starting Induction Motor Diagram

Full beginning obstruction is associated and in this manner the stockpile current to the stator is decreased. The rotor starts to turn, and the rotor protections are continuously removed as the speed of the engine increments. At the point when the engine is running at its evaluated full burden speed, the beginning protections are removed totally, and the slip rings are short-circuited.

Three-stage with electronic control (variable recurrence drive), it is easy to control the speed and heading of a three-stage acceptance engine. Single-stage, not really basic. Three-stage engines are innately self-beginning. Single-stage engines require a different beginning winding. Switching a solitary stage engine requires truly reconnecting that starts winding. Three stages are more reasonable, without a doubt.

3.4 Decelerate the Speed of the Electric Vehicle

Deceleration is likewise a significant variable. On deceleration, electric vehicles utilize the turning of the engine to create power to input into the battery. This is called regenerative slowing down. It seems like applying the brakes since there is an attractive opposition against the engine's turning while it goes about as a generator. In regenerative slowing down, active energy is being changed over into electrical energy. In ordinary slowing down, motor energy is being changed over absolutely into heat in the circles and brake cushions and is completely squandered. At the point when you are following behind ICE vehicles, each time their brake lights come on, it implies they are utilizing all the fuel they used to find a good pace as waste hotness in their slowing mechanisms. As an EV driver, each time you use your brakes, you are doing the very same thing, so slows down are to be kept away from. I view that as, aside from surprising occasions or reaching a dead stop at intersections, traffic lines, and traffic signals, all my speed control is finished by regenerative slowing down. That way I'm getting back a portion of the battery power I utilized in speed increase, however know that it isn't every last bit of it - regenerative slowing down is just around 60% proficient, meaning you just get back around 60% of the electrical energy it took to find a workable pace when you delayed down utilizing regenerative slowing down.

The way that regenerative slowing down is just 60% proficient in recovering the energy exhausted in speed increase should make it clear to anybody that that metropolitan driving gives more noteworthy reach due to the halting and beginning (regenerative slowing down) is a legend. Indeed, it is the situation that in metropolitan driving, each speed increase is taking extra energy from the battery, and each deceleration utilizing regenerative slowing down is just returning 60%, best case scenario, of what was used in that speed increase. Metropolitan driving will give less reach than driving at a similar normal speed, at a consistent speed, on a straight and level street. The main thing that makes metropolitan driving yield a superior reach is that less battery power is consumed in conquering air opposition on the grounds that at the low rates in metropolitan getting there is next to no air obstruction.

3.5 Induction Motor Starts Electrical Vehicle

As a result of the intricacy of the point, coming up next is an improved on clarification of how a four-shaft, three-stage AC enlistment engine works in a vehicle. It begins with the battery in the vehicle that is associated with the engine. Electrical energy is provided to the stator by means of the vehicle's battery. The curls inside the stator (produced using the directing wire) are organized on inverse sides of the stator center and go about as magnets, as it were. Subsequently, when the electrical energy from the vehicle battery is provided to the engine, the loops make pivoting, attractive fields that pull the directing poles outwardly of the rotor along behind it. The turning rotor makes the mechanical energy expected to turn the pinion wheels of the vehicle, which, thus, pivot the tires. Presently in an average vehicle, i.e., non-electric, there is both a motor and an alternator. The battery drives the motor, which controls the cog wheels and wheels. The pivot of the wheels then, at that point, drives the alternator in the vehicle and the alternator re-energizes the battery. To this end you are told to drive your vehicle around for a period in the wake of being hopped: the battery should be re-energized to work properly. There is no alternator in an electric vehicle.

All in all, how does the battery re-energize then, at that point? While there is no different alternator, the engine in an electric vehicle goes about as both engine and alternator.

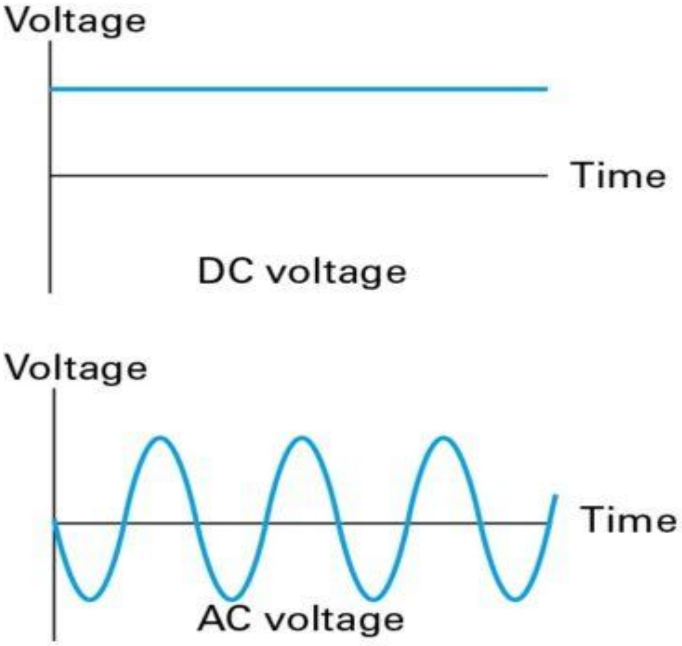


Figure 3.11: Induction Motor V/T Comparison

Fig. 1. The term substituting flow characterizes a sort of power portrayed by voltage and current that shifts regarding time. This is because of the substituting idea of the air conditioner signal that permits the voltage to be effectively moved forward or ventured down to various qualities. That is one reason why electric vehicles are so one of a kind.

As referred to over, the battery turns over the engine, which supplies energy to the cog wheels, which pivots the tires. This interaction happens when your foot is on the gas pedal - the rotor is pulled along by the pivoting attractive field, requiring more force. In any case, what happens when you let off of the gas pedal? At the point when your foot falls off the gas pedal the turning attractive field stops and the rotor begins turning quicker (rather than being pulled along by the attractive field). At the point when the rotor turns quicker than the pivoting attractive field in the stator, this activity re-energizes the battery, going about as an alternator.

3.5.1 Voltage per Hertz Control of Induction Motor

V/Hz control keeps a steady proportion between voltage (V) and recurrence (Hz). Shifting the voltage recurrence influences both the engine speed and the strength of the attractive field. At the point when the recurrence is brought down (for slower engine speed), the attractive field increments and inordinate hotness is created. This speed control strategy is known as Volts per Hz. Above evaluated speed, the applied voltage is generally kept steady at appraised esteem; this activity is alluded to as consistent HP. At low frequencies (for example speeds), the voltage should be supported to make up for the impacts of the stator opposition.

Volts/Hertz control originates from the voltage-recurrence relationship and how it connects with attractive motion in Faraday's Law

$$V = N\frac{\Delta\varphi}{\Delta t}$$

Where V is the EMF-incited in a loop, N is the quantity of turns, and φ is the attractive transition. It very well may be shown that.

$$\varphi = \left(\frac{V}{f}\right) * K$$

Where K is a steady and f is the recurrence of the stock. If the proportion V/f is consistent, the attractive transition will likewise be steady. As such, the voltage-recurrence relationship should be direct assuming that a steady transition is wanted. Moreover, assuming transition is steady, so is an acceptance engine's force for a given stator current. In this way, steady volts-hertz control has a consistent force trademark which is appealing for some modern applications.

3.5.2 Size and Characteristics of Three-Phase Induction Motor Drives

Within the stator, three-phase currents form a rotating magnetic field, which induces a current and a magnetic field in the rotor. As the rotor slips a little behind the revolving stator field, rotor torque develops. Polyphaser induction motors, unlike single-phase motors, are self-starting.

A typical motor will be between 20,000 and 30,000 watts. A typical controller will have a power rating of 40,000 to 60,000 watts (for example, a 96-volt controller will deliver a maximum of 400 or 600 amps).

CHAPTER 4

MOTOR DRIVES FOR ELECTRIC VEHICLE

4.1 Introduction

Currently, induction drives are the most advanced technology among non-removable motor drives. There are two types of induction machine (IM): wound-rotor and squirrel-cage. Due to the high cost, the need for repairs and the lack of rigidity, the rotor induction motor is less attractive than a squirrel-cage motor, especially for electric and electric vehicles (EV). Hence, the squirrel-cage induction motor is also referred to as the induction motor for EV propulsion. In addition to the common advantages of non-commutatorless motor drives, motor induction has the obvious advantage of low cost and low cost. These advantages may outweigh their major disadvantages of controllability as well as support technology that is well-accepted for EV.

4.2 System Configurations

The basic configuration of an induction motor drive is shown in Figure 4.1. It consists of a three-phase squirrel-cage induction motor, a three-phase voltage-fed pulse-width modulated (PWM) inverter, an electronic controller, and some sensors.

For EV propulsion, the system configuration can be single-motor or multiple-motor. The single-motor configuration of the induction motor drive has been widely adopted for commercial EVs. As shown in Figure 4.2, the single-motor configuration uses only one IM and one PWM inverter, which can minimize the corresponding size, weight, and cost. However, it needs a differential to adjust the relative speeds of the driving wheels for cornering. In addition, it generally employs a fixed gear (FG) to reduce the motor speed to match with the wheel speed. It should be noted that the high-speed design of IMs is widely adopted for EV propulsion because this design favors the reduction of machine size and weight, which are crucial factors for EVs.

On the other hand, the design of most motors uses multiple motors to drive itself. As shown in Figure 4.3, the motor configuration of the induction motor drive has two IM, two PWM inverters, and two FG options depending on whether the drive is used directly or not. Since the two IMs are controlled independently, different functions can be performed on the computer, thus removing large and heavy objects. Whether IM accepts high speed design or low speed design depending on trade-offs using FG. The main concern is that you have a multi-motor

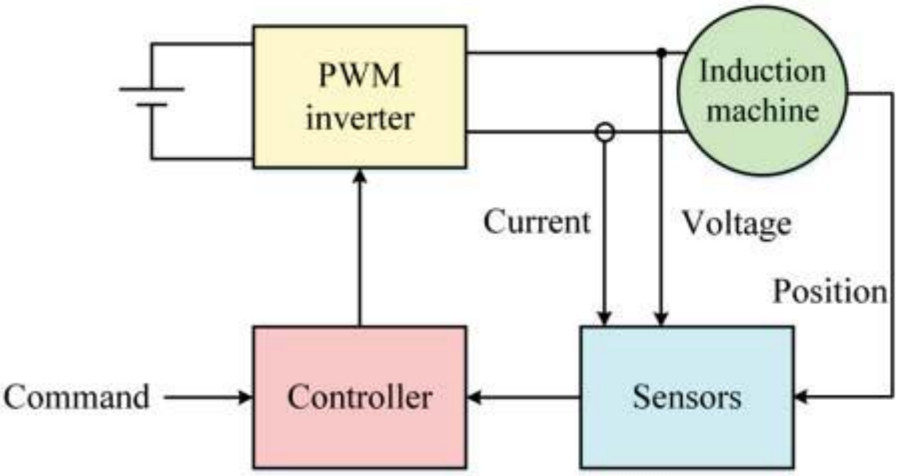


Figure 4.1 Basic configuration of induction motor drive

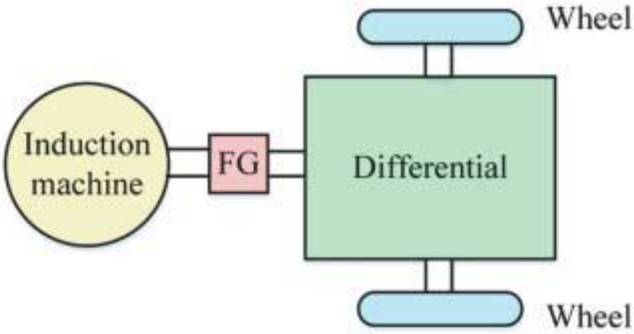
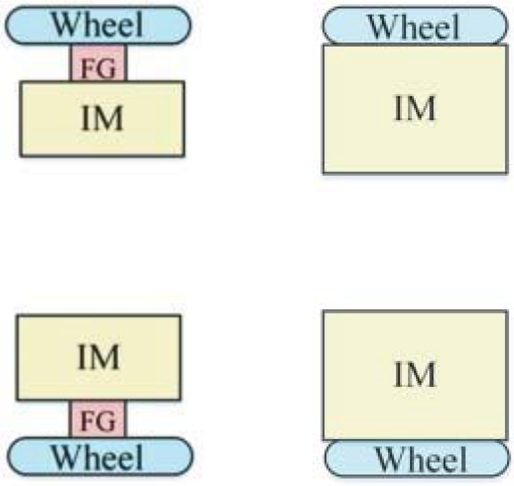


Figure 4.2 Single-motor configuration of induction motor drive for EVs



(a) **(b)**

Figure 4.3 Dual-motor configurations of induction motor drive for EVs: (a) high-speed geared structure and (b) low-speed gearless structure

Designing for business EVs is a safety issue. If the speed limit for left and right IM is calculated incorrectly or accidentally damaged, corner behavior will be catastrophic. Another control factor and admission error is inevitable.

4.3 Induction Motor Control

There are three main types of control strategies for induction motor drives: the variable-voltagevariable-frequency (VVVF) control, field-oriented control (FOC), and direct torque control (DTC). Hereby, they are described in detail.

4.3.1 Variable-Voltage Variable-Frequency Control

VVVF controller has been approved for speed control of induction drives. It is based on constant voltage volts / hertz control for frequencies below the frequency range, as well as constant voltage control for frequency exceeded frequencies. For short periods of time, a voltage boost is applied to compensate for the difference between the applied voltage and the EMF [36].

Referring to the equivalent circuit in which $Rm$is neglected, the magnetizing current Imat the rated speed can be expressed as

$$I_m = \frac{E'_{r\_\mathrm{rated}}}{X_m} = \frac{E'_{r\_\mathrm{rated}}}{f_{\mathrm{rated}}} \frac{1}{2\pi L_m}$$

where*E′r*rated is the back EMF at the rated frequency and *Lm* is the magnetizing inductance. Below therated speed, the operating frequency *f* can be normalized as a frequency ratio *a*, which is defined as

***a* = *f*∕*f*rated**

Hence, the corresponding magnetizing current can be expressed as

$$I_m = \frac{E'_r}{aX_m} = \frac{E'_r}{af_{\mathrm{rated}}} \frac{1}{2\pi L_m}$$

The magnetizing current and hence flux will remain constant if *E′r*= *aE′r*rated or simply called constant*E*∕*f*. Consequently, the corresponding maximum torques, both during motoring and generating, remainconstant as given by

$$T_{\max} = \pm\frac{3}{2\omega_s} \frac{E'^2_{r\_\mathrm{rated}}}{X'_r}$$

Because the measurement of the back EMF is very difficult, the applied voltage is generally adopted toapproximate the back EMF. Thus, the desired constant E∕f strategy is approximated by the constant V∕fstrategy for most operating frequencies, except under low frequencies for low-speed operation. At low speeds, the stator impedance drop becomes appreciable so that the applied voltage can no longer be valid to approximate the back EMF. Thus, a boosting voltage is normally required to compensate for the stator impedance drop for low-speed operation using the constant V∕f strategy.

Above the rated speed, the applied voltage is kept at the rated voltage Vrated, while the operating frequencyis increased above the rated frequency. Hence, the maximum torque decreases with the increase in frequency (a > 1) as given by

$$T_{\max} = \frac{3}{2a\omega_s} \left[\frac{V^2_{\mathrm{rated}}}{R_s \pm \sqrt{R_s^{\,2} + a^2\left(X_s + X'_r\right)^2}} \right]$$

Since the slip is small, the rotor current is almost in phase with the back EMF. When neglecting the rotorresistance loss and stator impedance drop, the output power is equal to the product of rated voltage and rotor current. Thus, under the maximum permissible stator current, this variable-frequency control offers constant-power operation.

Beyond the critical speed, the motor is operated at the slip for the maximum torque. Both the current and power of the motor are allowed to decrease inversely with speed, and the torque decreases inversely as the speed squared.

In summary, the speed characteristics of the drive induction motor are shown using the VVVF controller in Figure 4.4, and the corresponding speed capacity is shown in Figure 4.5. It can be seen that there are three active areas. The first area is called the constant variable area in which the motor can deliver its maximum power for low-velocity speeds (commonly called ωb speeds). In the second zone, called the permanent energy zone, it is gradually increased.

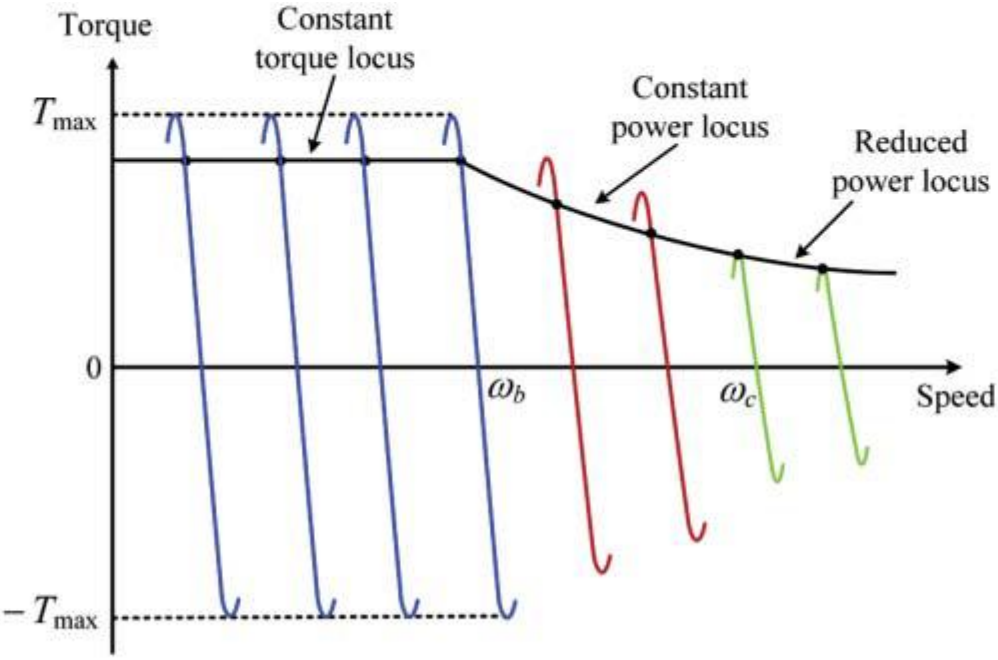


Figure 4.4 Torque-speed characteristics of VVVF-controlled induction motor drive

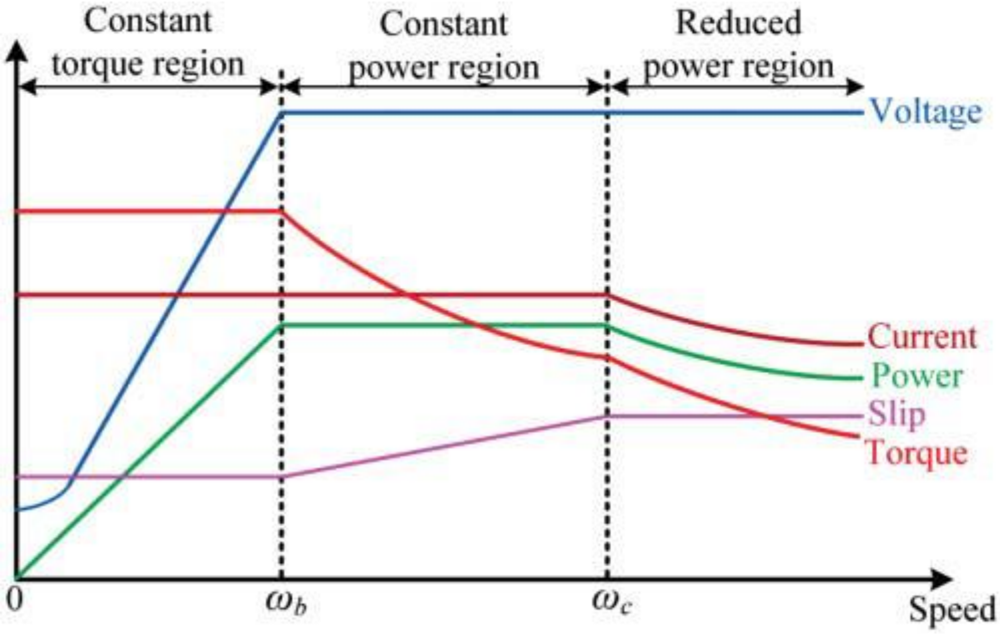


Figure 4.5 Operating capabilities of VVVF-controlled induction motor drive

And the maximum value so that the stator current remains constant and the motor can maintain its rated power. When the top speed is too high ωc, the dissipation remains constant while the current stator is reduced. Therefore, the torque force decreases in square of velocity, the so-called power zone decreases.

It should be borne in mind that both air flow and air flow under VVVF control is a function of voltage and frequency. The effect of this link is actually the cause of the energy response. That is, the corresponding torque control is slow and accurate for application for high EVs.

4.3.2 Field-Oriented Control

To improve the power efficiency of induction drives, FOC is better than VVVF control. By using FOC, the mathematical model of induction motor is first modified from a – b – c frame straight to the ds – qs frame, and then into a de-qe frame running ωe. as shown in Figure 3.19. Therefore, in the vertical position, all the sinusoidal changes in the center such as stator voltage vs, stator current is, stator flux linkage ,s, rotor voltage vr, rotor current ir and rotor flux linkage nwerer can be represented by DC values in a. the center rotates at the same time [37] [38].

Firstly, taking θ as the angle between the q^s-axis of the d^s–q^s frame and the a-axis of the a-b–c frame, the transformed variables in the d^s–q^s frame can be expressed as

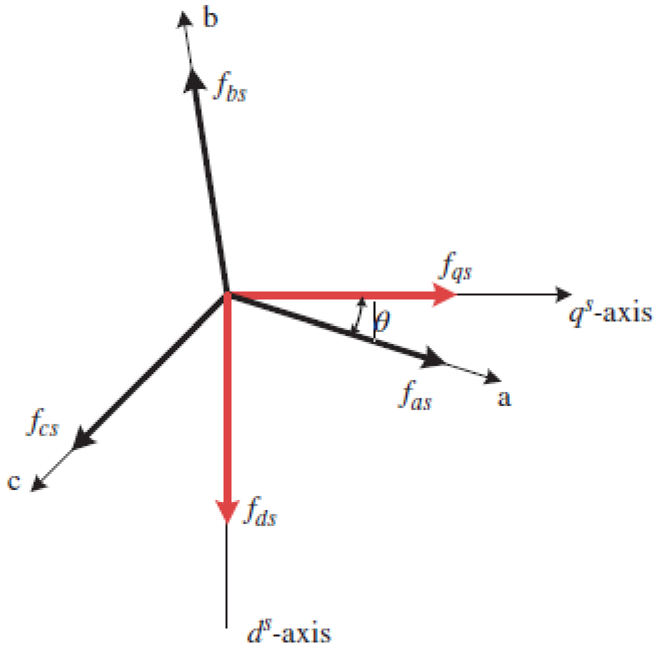
$$\begin{bmatrix} f_{ds}^{s} \\ f_{qs}^{s} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\theta & \sin\left(\theta - 120^\circ\right) & \sin(\theta + 120^\circ) \\ \cos\theta & \cos(\theta - 120^\circ) & \cos(\theta + 120^\circ) \end{bmatrix} \begin{bmatrix} f_{as} \\ f_{bs} \\ f_{cs} \end{bmatrix}$$

Where f can be any circuit variable such as voltage, current, flux linkage and the superscript s refers to the variable that is on the stationary d^s–q^s frame. Normally, it is convenient to set $\theta = 0$ so that the q^s-axis is aligned with the a-axis.

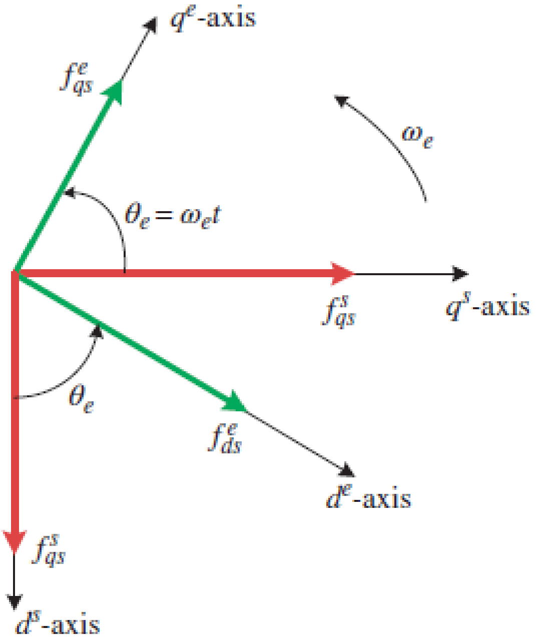
Secondly, as the d^e–q^e frame rotates synchronously at speed ωe, the angle between the d^e–q^eframe and the d^s–q^s frame is $\theta e = \omega et$. Thus, the transformed variables in the d^e–q^e frame can be obtained as

$$\begin{bmatrix} f_{ds}^{e} \\ f_{qs}^{e} \end{bmatrix} = \begin{bmatrix} \cos\theta_e & \sin\theta_e \\ -\sin\theta_e & \cos\theta_e \end{bmatrix} \begin{bmatrix} f_{ds}^{s} \\ f_{qs}^{s} \end{bmatrix}$$

where the superscript e refers to the variable that is on the synchronously rotating d^e–q^eframe.



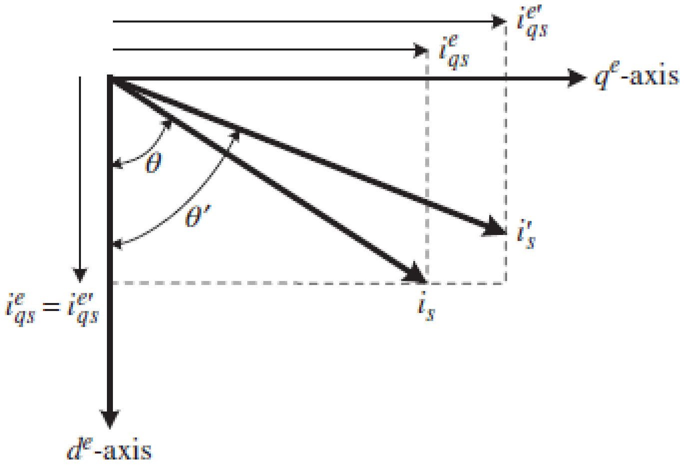
(a)



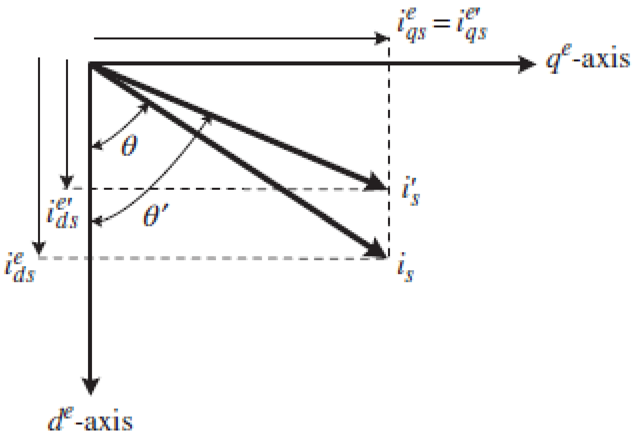
(b)

Figure 4.6 Coordinate transformations for FOC: (a) stationary a–b–c frame to stationary d^s–q^s frame and (b) stationary d^s–q^s frame to synchronously rotating d^e–q^e frame.

Consequently, the control principles, namely the increase of torque and the flux weakening, are depicted in Figure 4.7.



(a)



(b)

Figure 4.7Principles of FOC: (a) torque control and (b) flux control

There are two ways to implement FOC for motor induction drives: direct and indirect. Specific FOC, also called instantaneous vector control, is used to determine the correlation of the flux rotor directly by the size of the air gap or by measuring the change from the stator voltage measured in current. Air conversion rates can be achieved by using Hall sensors or a microphone. However, the rise of the Hall Effect and the air gap are prone to mechanical vibration and temperature fluctuations, which are insignificant under the hard work of EV. In addition, the optical cable suffers from the problem of low voltage effects and excessive signal and poor noise, which makes it impossible.
to provide air-outflow conversion during low-performance operation. On the other hand, the connection of the flux rotor can be defined using stator voltage equation, which depends on the airport voltage and current as well as the machine parameters Rs, Lm, Ls, and Lr. However, at low speeds, the measured voltage signal is small, which is not good for estimation. At present, the connection of the flux rotor can be explained by using the rotor voltage control, which depends on the current size and speed as well as the machine Rr, Lm and Lr. While this method takes advantage of the fact that the projection may fall into zero speed, it requires the correct input speed. These binary systems are completely dependent on the machine area proper compensation for the variance is desirable.

Indirect FOC, also known as indirect vector control, is widely used by induction motor drives for EV propulsion. This technique does not require specifying the rotor flux linkage. The key is to calculate the slip velocity required to infer the rotor instantaneous flux position θe for correct field orientation:

$$\theta_e = \int_0^t \omega_e dt = \int_0^t (\omega_{sl} + \omega_r) dt = \int_0^t \omega_{sl} dt + \theta_r$$

Where ω_e is the synchronous speed, ω_{sl} is the slip speed, ω_r is the rotor speed, and θ_r is the rotor positionthat is real-time measured by using a position encoder.

Despite the fact that the FOC has not been significantly used for high-performance motor induction drives, it still has some drawbacks. In particular, the permanent rotor time (r (which has the greatest effect on the switching mode) changes significantly from operating mode as well as magnetic saturation, leading to invisible FOC damage. Now, there are two good ways to solve this problem. One way is to do regular internet rotor time identification as well as update the parameters used in the invisible FOC control. Another way is to adopt sophisticated control algorithms to make the FOC controller invisible without affecting the motor size difference. A magnetic resonance change control (MRAC) control system has been developed for induction FOC of induction motor. Basically, an adaptive system that forces motorists to follow the steering system even under different operating systems is accepted as a permanent rotation of the rotor due to long operation. The obvious advantage of this MRAC feature is that it is not necessary to make a clear parameter identification.

4.3.3 Direct Torque Control

DTC is an advanced scalar management feature that can provide performance compared to FOC for induction drives. The plan is to immediately control the stator flux and torque connection by selecting the correct type of switch for the PWM inverter voltage supply. The choice was made to prevent torque and flux faults in various types of threats and flux hysteresis bands, so as to obtain a quick response and change management [39] [40].

In the IM, the electromagnetic torque can be expressed in the form of cross product of the stator flux linkage vector λ_s and the stator current vector i_s as given by

$$T_e = \frac{3}{2}\frac{P}{2}(\lambda_{ds}^s i_{qs}^s - \lambda_{qs}^s i_{ds}^s) = \frac{3}{2}\frac{P}{2}(\bar{\lambda}_s \times \bar{i}_s)$$

The control block diagram of DTC for the induction motor drive is depicted in Figure 4.8. The torquecommand $T*_e$ and flux command $\lambda*_s$ are compared with the respective estimated values, and the errors (ΔT_e and $\Delta \lambda_s$) are processed through the respective hysteresis controllers, which are defined as

$$\delta T_e = \begin{cases} 1 & \text{for } \Delta T_e > H_T \\ 0 & \text{for } -H_T < \Delta T_e < H_T \\ -1 & \text{for } \Delta T_e < -H_T \end{cases}$$

$$\delta \lambda_s = \begin{cases} 1 & \text{for } \Delta \lambda_s > H_\lambda \\ -1 & \text{for } \Delta \lambda_s < -H_\lambda \end{cases}$$

Whereas HT is the hysteresis of the three-phase torque controller and Hλ is the hysteresis of the two-phase torque control. The projector serves to calculate the connection of the torque to the stator flux as well as the parts for the section selection based on the measured voltage and water. This DTC induction motor drive can operate easily in all four directions, providing torque response compared to that using FOC.

As compared with the FOC, the DTC for the induction motor drive possesses some definite advantages:

- There is no need to use coordinate transformations that are computationally intensive.
- There is no need to perform feedback current control.
- The motor torque can be directly controlled so that the torque response is much faster.

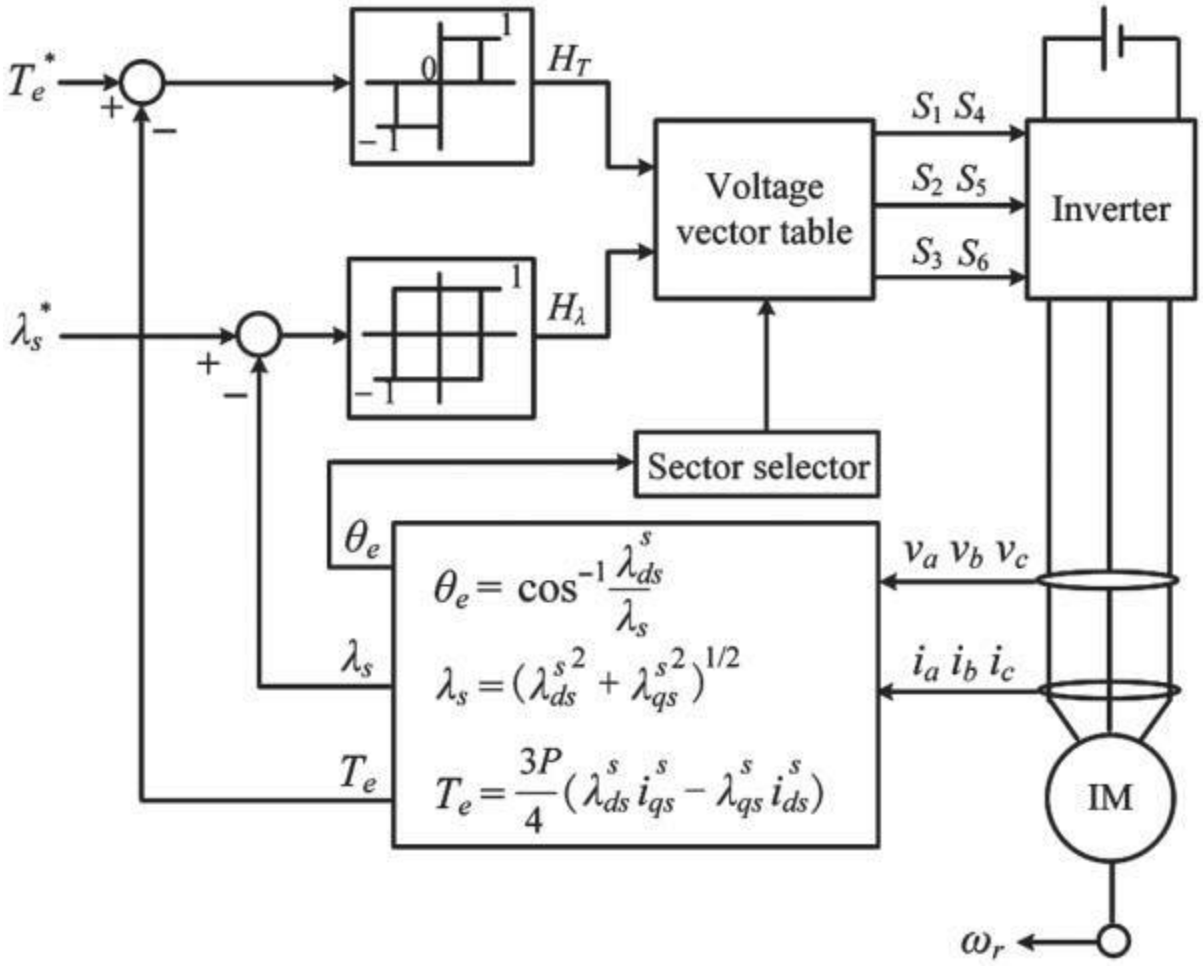


Figure 4.8 DTC block diagram for induction motor drive

However, DTC suffers from relapse of energy response during onset and high torque ripple. There are a number of possible alternatives such as the inclusion of a nonlinear argument in the selection scheme of stator voltage vectors and the use of forecasting to select the conversion state.

CHAPTER 5

HOW TO CHARGE BATTERY

5.1 Introduction

There are many fancy algorithms for battery chemistry. They aim to charge quickly and detect when the battery is full so they don't break. This full charge detection may depend on a change in the effective series resistance of the battery. Rate of change of voltage at rated current or direct temperature measurement the simplest and most reliable are constant current to constant voltage. This will work for battery chemistry.

5.2 Procedure of different stepsfor charging of lead acid battery

Lead acid uses a voltage-based algorithm for charging. The charging time of sealed lead-acid batteries is 12-16 hours, for large stationary batteries it is 36-48 hours with high charge current and multi-phase charging method. Charging time is reduced to 10 hours or less. However, recharge may not be complete. Lead acid is slow and doesn't charge as fast as other battery systems.

Lead acid batteries must be charged in three steps: [1] constant current charge, [2] topping charge, and [3] floating charge. The constant current charge covers most of the charge and lasts almost half of the required charge time. The filling charge continues with a low charge current and provides saturation and compensates for the damage caused by the self-discharge.

Charge stages of a lead acid battery

The battery is charged fully when the current drops to a determined level or level 2. Charging voltage will be reduced to full charge.

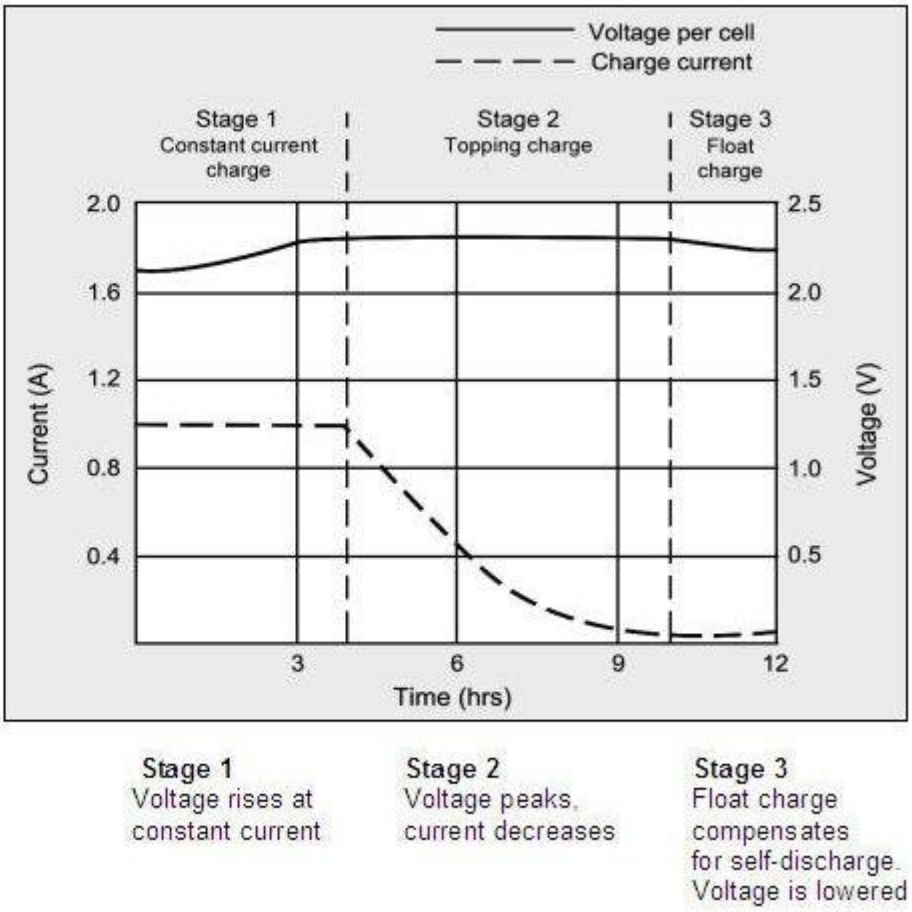
Figure 5.1 Lead Acid Battery

During charging time, the battery charges 70 percent within 5-8 hours; The remaining 30 percent are full and the payment process gradually takes another 7-10 hours. Charging is important for the quality of the battery and can be compared to a short break when the food is good. If it is removed, the battery will eventually lose its ability to fully charge and its performance will decrease due to sulfation. The charge on the water at the third level keeps the battery and charger fully charged.

Switching from level 1 to 2 appears to occur safely when the battery reaches a certain rated voltage. The current starts to drop as the battery starts to saturate, and full charge is obtained while the current is reduced to three percent of the current level. Batteries with high leaks may not be able to achieve current saturation at low, and a flat timer takes over the charging cycle.

The correct setting of the charger voltage is critical and ranges from 2.30 to 2.45V per cell. Setting the voltage gate is a contraction, battery experts refer to this as "dancing on the needle head." On the one hand, the battery needs to be fully charged to achieve maximum capacity and avoid sulfation on the plate is not good; On the other hand, overheating conditions lead to corrosion grid on the plate and lead to gassing. To make the "dancing on the needle" harder, the battery pack adjusts in temperature. Warmer environments require lower voltage thresholds and in colder climates prefer higher temperatures. The charger reveals that temperature changes should include a temperature sensor to adjust the charger voltage for optimal charger performance. If this is not possible, it is better to choose a lower voltage for storage.

Once fully charged by saturation, the battery should not live at a voltage higher than 48 hours but should be reduced to the above-mentioned voltage level. This is especially important for closed systems because these systems are less likely to tolerate large-scale flooding. Charging more than what the battery can irritate turns into useless energy hot when the battery starts to gas. The recommended surface temperature for most lead acid batteries is 2.25 to 2.27V / cell. (Large battery batteries float at 2.25V and 25 ° C (77 ° F.) Manufacturers recommend lowering the charge over water at a temperature above 29 ° C (85 ° F).



Many charged batteries are kept afloat. To reduce stress, a substance called hysteresis removes the current floating when the battery is fully charged. As the peak voltage fluctuates due to self-discharge, the occasional charge replenishes lost energy. Of course, batteries are only borrowed from time to time for a short period of time. This type works well for load-bearing installations when ready.

Lead acid batteries should always be kept in a charged state. An investment charge should be made every three months, at least, to prevent the voltage falling below 2V / cell.

5.3 Procedure of different stepsfor charging of GEL battery

Yes generally Gel charge ratio and typically the volt should be between 13.8 vdc to 14.8 vdc with current limiter equal to the decimal ratio of your battery.

Figure 5.2 Gel battery

1. The first step is a bulk charger, where up to 80% of the battery power is replaced by a high voltage and current amp level of the charger.

2. When the battery voltage reaches 14.4 volts this step starts the absorption charge. This is where the voltage is maintained at 14.4 volts permanently and the current (amps) goes down until the battery is 98% charged.

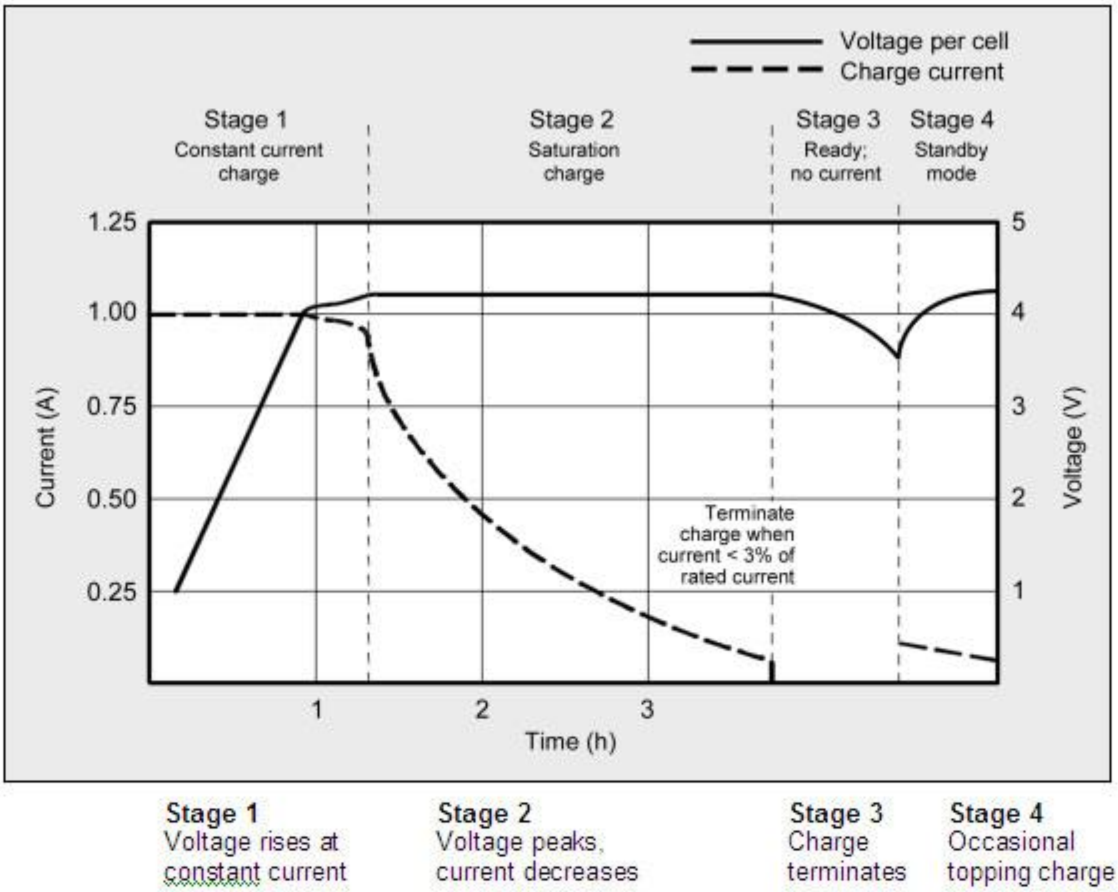
3. Next step Float. This is a controlled voltage that will not exceed 13.4 volts and is usually less than 1 amp current. This time will bring the battery 100% charged or close. The floating battery will not boil or heat the battery, but it will keep the battery 100% ready and prevent cycling during not working for a long time. Note: Some gel cells and AGM batteries may require special settings or a charger.

5.4 Procedure of different stepsfor charging of Lithium ION battery

The charging process of lithium ion battery is divided into two parts: the current charging system at voltage reduces the charging time. Excessive charging and discharge of lithium-ion batteries can cause permanent damage to both positive and negative electrodes. Excessive removal leads to the failure of the carbon dioxide system, and the failure may result in the introduction of lithium ions during charging; Excessive charge causes excessive lithium ions to form in the negative carbon system, and some lithium ions can no longer release it.

Figure 5.3 Lithium ION Battery

Lithium-ion batteries retain the best performance of charge and discharge path for shallow charger and shallow charger. Overall, 60% DOD is 2 to 4 times the life cycle below 100% DOD.



Phase 1: Trickle Charge - Trickle charge is used to charge the battery. When the battery voltage is lower than about 3V, the battery is first charged with a constant current of up to 0.1C.

Phase 2: Constant Current Charging—when the battery voltage rises above the charger area, the charger current is increased for constant charging. Current values for chargers always range between 0.2C and 1.0C.

Phase 3: Constant Voltage Charging - When the battery voltage rises to 4.2V, the charger charges all the time off and the charger voltage process always starts. For best performance, the acceptance should be better than + 1%.

Stage 4: Charging Termination - Unlike nickel batteries, continuous Li-ion battery charging is not recommended. Ongoing charging can cause plate and lithium plate effects. This can lead to improper battery operation and the risk of accidental failure.

CHAPTER 6

SIMULATION USING PROTEUS

6.1 Introduction

Depending on the region and requirements, electric vehicles (EVs) can be charged in a variety of methods. As a result, EV charging systems come in a variety of shapes and sizes, each tailored to a specific application. Electric vehicle chargers, also known as electric vehicle supply equipment (EVSE), have different specifications and requirements in different countries, depending on the available EV models on the market and the features of the power system. The conductive charging requirements of an EVSE are determined by parameters such as vehicle type, battery capacity, charging techniques, and power ratings. The simulation description is given below in this chapter.

6.2 Simulation Description

A transformer and a bridge rectifier are included in the power supply. The supply of direct current (DC) to the battery pack is required for EV charging. A converter is necessary to give DC power to the battery since electrical distribution systems provide alternating current (AC) power. AC or DC conductive charging is possible.

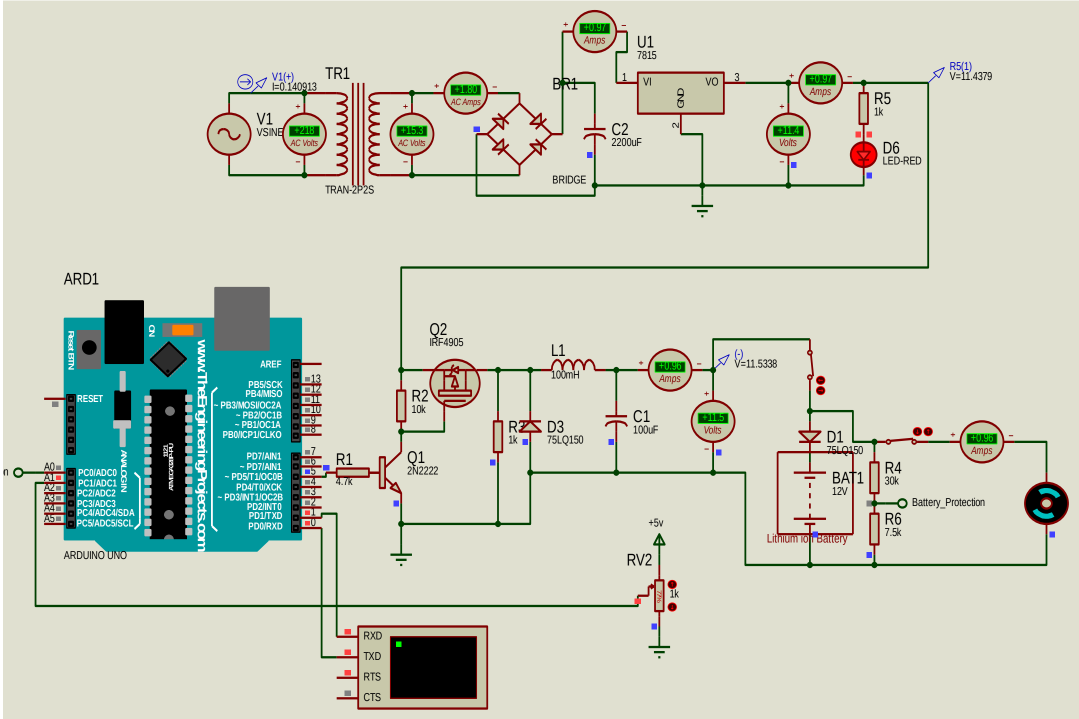


Figure 6.1: Simulation EV charging system

6.2.1 Circuit Operation

AC Source:

In this project, we set value for AC source 220 volts and frequency 50 hertz as we can see in the given figure 6.2.

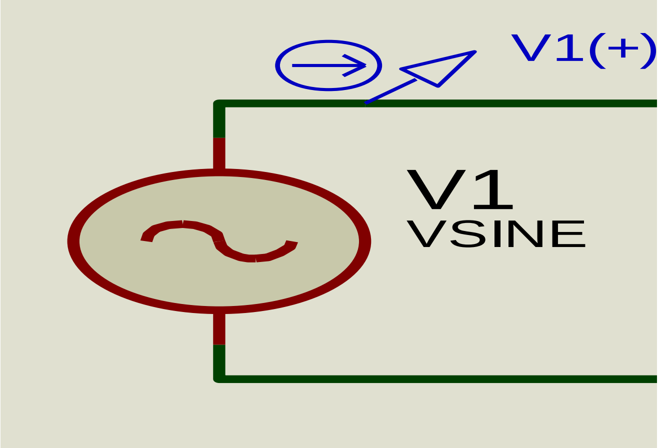


Figure 6.2: AC Source

Transformer:

After that set, the values of the transformer connected with the ac source as shown in the figure 6.3.

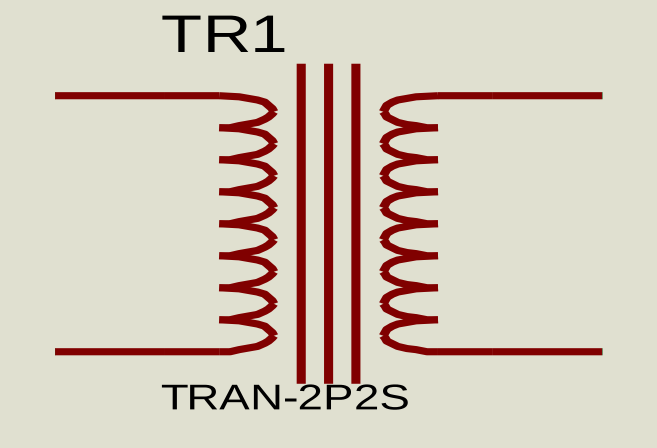


Figure 6.3: Transformer

Bridge Rectifier:

1. Construction of Full Wave Bridge Rectifier

- After that connect the bridge circuit with the transformer secondary winding that will rectify AC output of the transformer into DC.
- Four diodes (D1, D2, D3, and D4), a mutual inductor, and a load resistor make up the full-wave bridge rectifier circuit (RL). In a closed-loop bridge design, the four diodes

are connected together. The circuit diagram for the Bridge rectifier is shown in the graphic below:

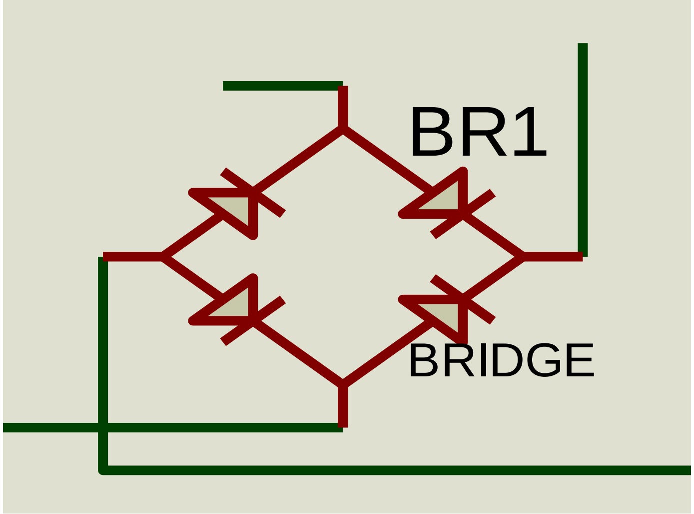


Figure 6.4: Circuit Diagram of Full-Wave Bridge Rectifiers

2. Working Principle of Bridge Rectifier

Terminal-1 of the inductor optional winding is positive (+) concerning Terminal-2 during the positive half-pattern of the air conditioner input voltage (Ground). Diodes D1 and D3 are forward one-sided in the present circumstance. Subsequently, current passes by means of diode D1, through the heap obstruction (RL), through diode D3, and back to terminal-2 (ground). Notwithstanding, on the grounds that diodes D4 and D2 are switched one-sided, power can't go through diodes D2. Subsequently, a main positive voltage is apparent across the heap resistor.

The terminal-2 of the transformer optional winding is positive (+) concerning terminal-1 during the negative half-pattern of the air conditioner input voltage (Ground). Diodes D2 and D4 are forward one-sided in the present circumstance. Accordingly, the current goes through diode D2 (CB arm), enters the heap obstruction (RL), and afterward goes through diode D4 (arm DA) prior to getting back to terminal-1 (ground). In any case, diodes D1 and D3 are converse one-sided, keeping current from moving through them (Abdominal muscle and DC arm). As in the past, positive voltage arises across the heap resistor in this situation.

Capacitor:

From that point onward, I have associated the capacitor of 2200uF with the extension circuit. A full-wave span rectifier creates a throbbing DC voltage with many waves that ascent to a most extreme and afterward tumble to nothing. This sort of DC voltage has no reasonable applications as a rule. Accordingly, we should change over throbbing DC voltage to smooth DC voltage, which can be refined utilizing a channel. As a channel, we'll use a capacitor that is resembled with the heap resistor (RL).

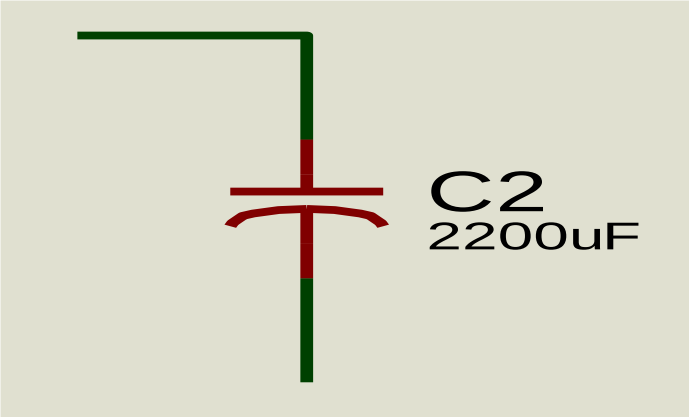


Figure 6.5: Capacitor

The capacitor is at first uncharged. The diodes D1 and D3 are forward one-sided during the primary positive half-cycle, and the capacitor starts to charge at a similar second. The capacitor is charged until the info arrives at its most extreme worth (Vp). The information voltage approaches the capacitor voltage now. At the point when the information voltage arrives at its most extreme worth, it begins to fall. At the point when the info voltage falls underneath Vp, the capacitor starts to release through the heap resistor, providing the heap current until the following pinnacle happens.

The following pinnacle shows up during the negative half-cycle, and diodes D2 and D4 are presently forward one-sided. Yet again therefore, the capacitor starts to charge until the info arrives at its most extreme worth (Vp). At the point when the information voltage falls underneath Vp, the capacitor releases again through the heap resistor, providing the heap current until the following pinnacle happens. This interaction rehashes the same thing again and over. Subsequently, across the heap resistor, we get a Smooth DC yield voltage (RL).

7815 IC:

In this project, I used the voltage regulator 7815 in conjunction with a circuit that converts the rectifier's output to 15 volts.

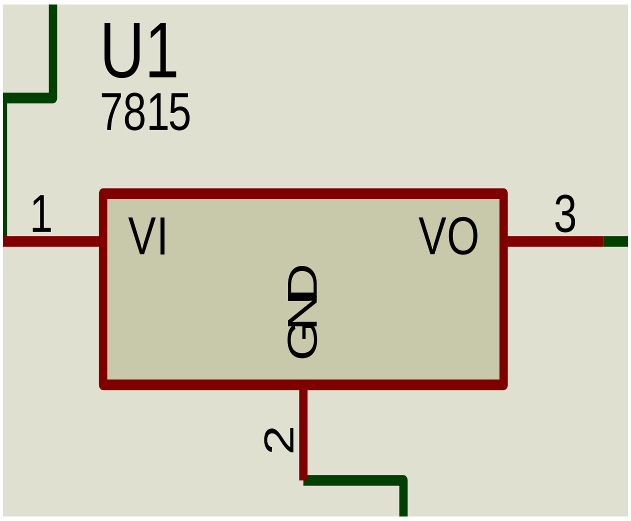


Figure 6.6: 7815 IC

This module, which belongs to the 78xx family of voltage regulators, is simple to use and inexpensive. The last two digits of this module's name indicate that it will regulate the voltage to 15 volts.

Red LED:

Also, connecting the red led and one-kilo ohm resistance with the voltage regulator as output

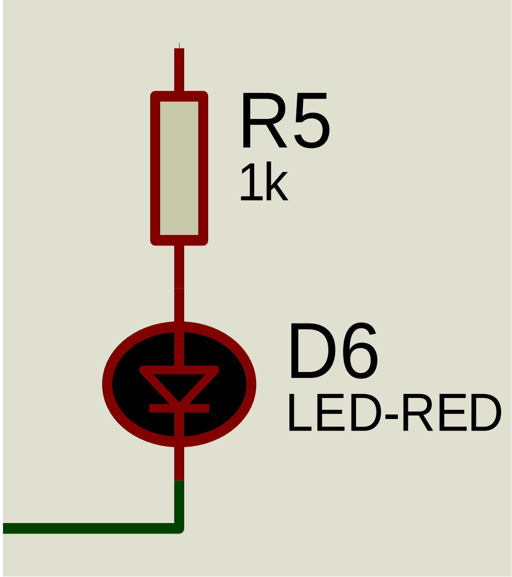


Figure 6.7: Red LED

Arduino UNO:

Here is used an Arduino UNO which is a microcontroller. It is the major components of this circuit.

- Atmega328p chip is used in the Arduino UNO board.

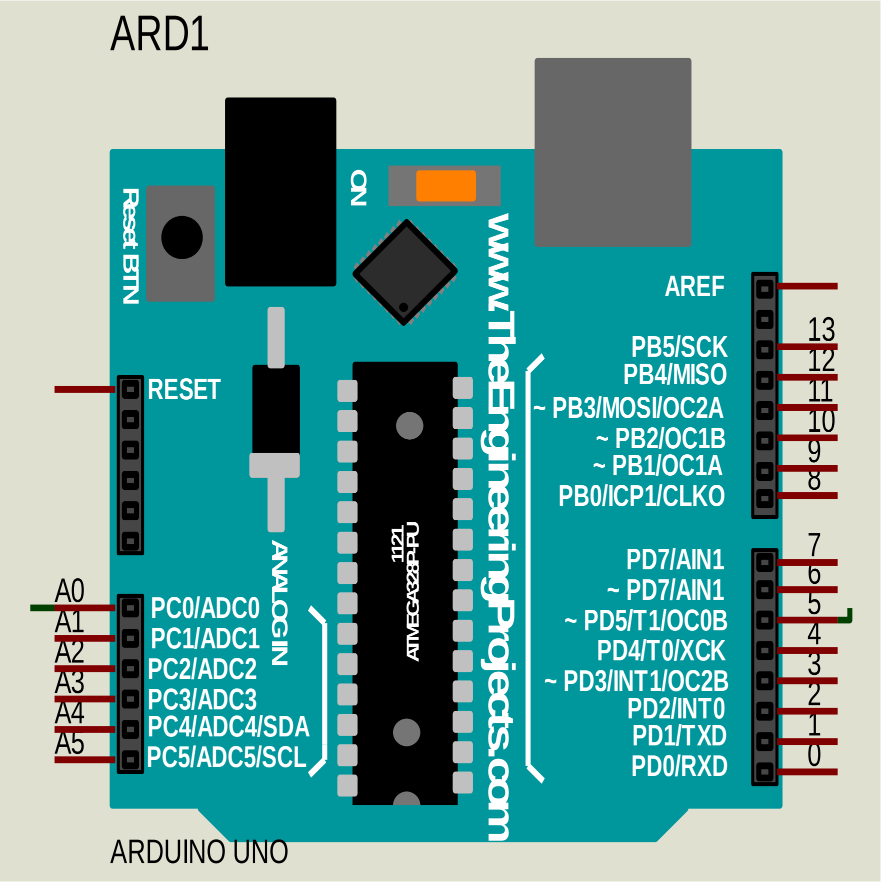


Figure 6.8: Arduino UNO

- Analog pins are 6.
- Arduino Uno has 14 digital input/output pins. Out of which 6 can be used as PWM outputs

IRF4905 MOSFET

Using a P channel IRF4905 MOSFET in these circumstances would be recommended, it greatly simplifies driving requirements, but it turns on when the gate is low,

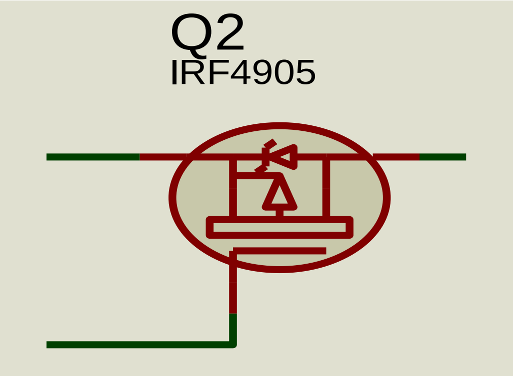


Figure 6.9: IRF4905 MOSFET

Schottky 10BW100 Diode:

- In this circuit, I have used 10BW100 Schottky diode.
- Since the general diode does not have to handle very high voltages, rather high currents, it would be a good design choice to use a Schottky diode with a low forward voltage drop to keep things efficient.

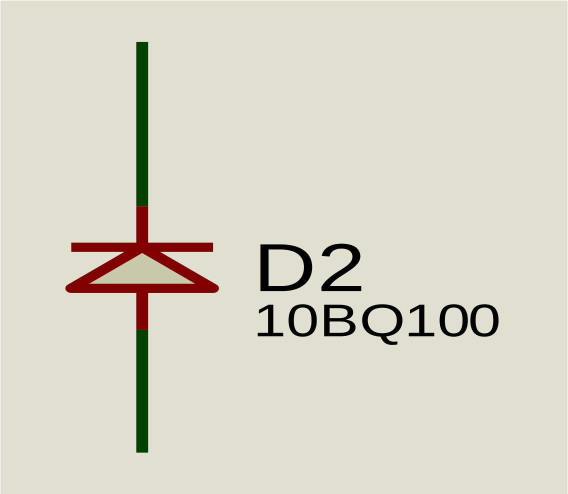


Figure 6.10: Schottky 10BW100 diode

Inductor:

- After that we have used 100mH inductor.
- An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy and transferring energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil around a core.

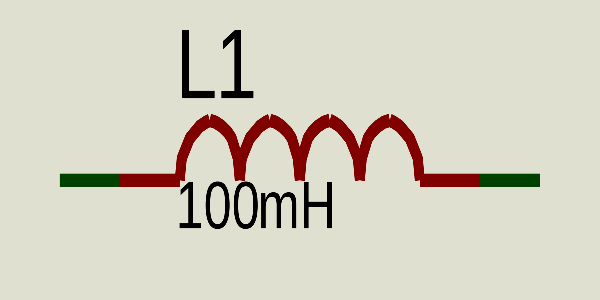


Figure 6.11: Inductor

Lithium Ion Battery:

- We have connected 3 cell lithium ion battery that battery cells can deliver up to 3.7 Volts.
- The 18650 cell has between 1800mAh and 3500mAh (mili-amp-hours).
- Charging time is 4 hr.

Figure 6.12: Lithium Ion Battery

CHAPTER 7

RESULTS AND DISCUSSIONS

7.1 Final Result

The battery voltage, charging current, and system temperature are all sensed by a microprocessor. The duty cycle of the PWM signal generated by the microcontroller with the feedback sensing signals determines the charging current completely [12]. The system was designed in such a way that once it is plugged in, no human hands are required to operate it. As a result, it can maintain a constant optimal charging current, safeguard the battery from overcharging, and provide a heat management solution that will extend both the system and battery life.

- A field test is done as well, to prove the success of the buck converter with MOSFET for EV.
- The test results shows that the applied voltage ranges produced are 14.3 to 14.5 V.
- The value of 14.5 V is obtained on the input voltage of 14.7; 14.8; 14.9; 15 and 16V.

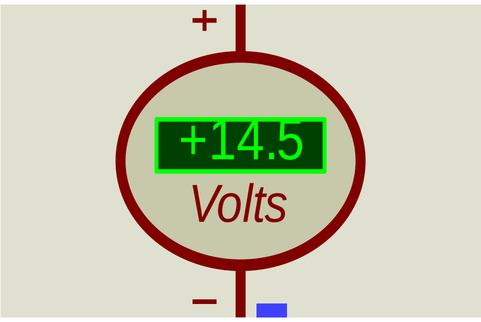


Figure 7.1: Result -I

Current ranges from 0.96A to 1 A.

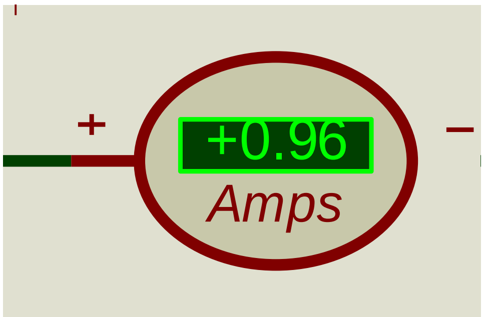


Figure 7.2: Result-II

Current Graph:

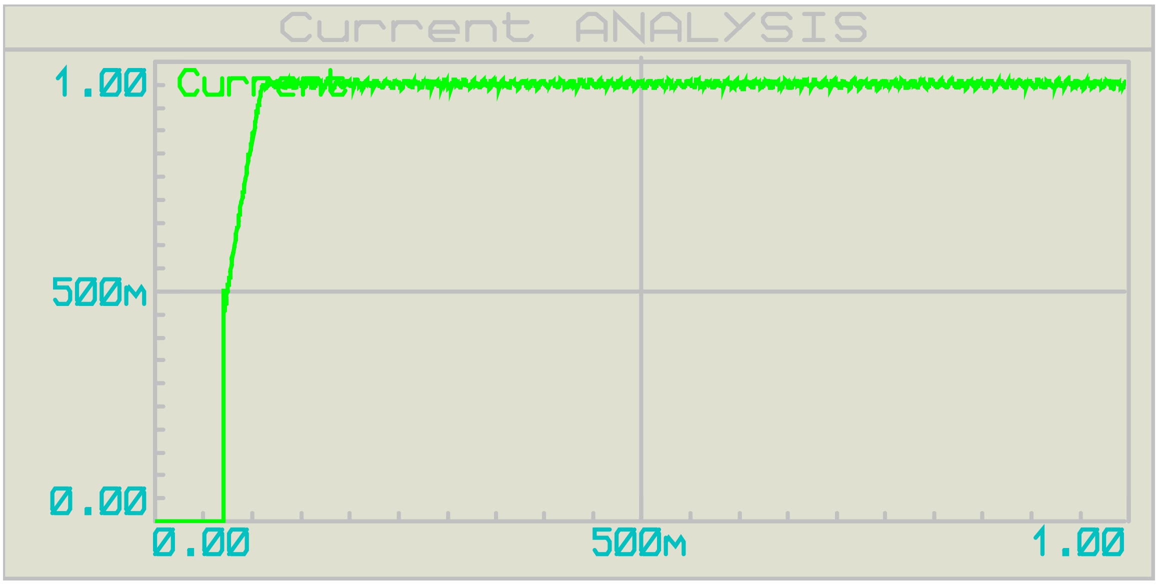


Figure 7.3: Final Result Current Graph of EVs Simulation

The current graph is shown in Figure 7.3. The y-axis shows the current values and the x-axis shows the simulation time values. The graph shows that the value of current is slightly curved upwards from 0.1 time point to 0.96 ampere. So we can see from the graph that the output value of current is 0.96 ampere. The value of the output current is less than 0.9 to 1 ampere.

Voltage Graph:

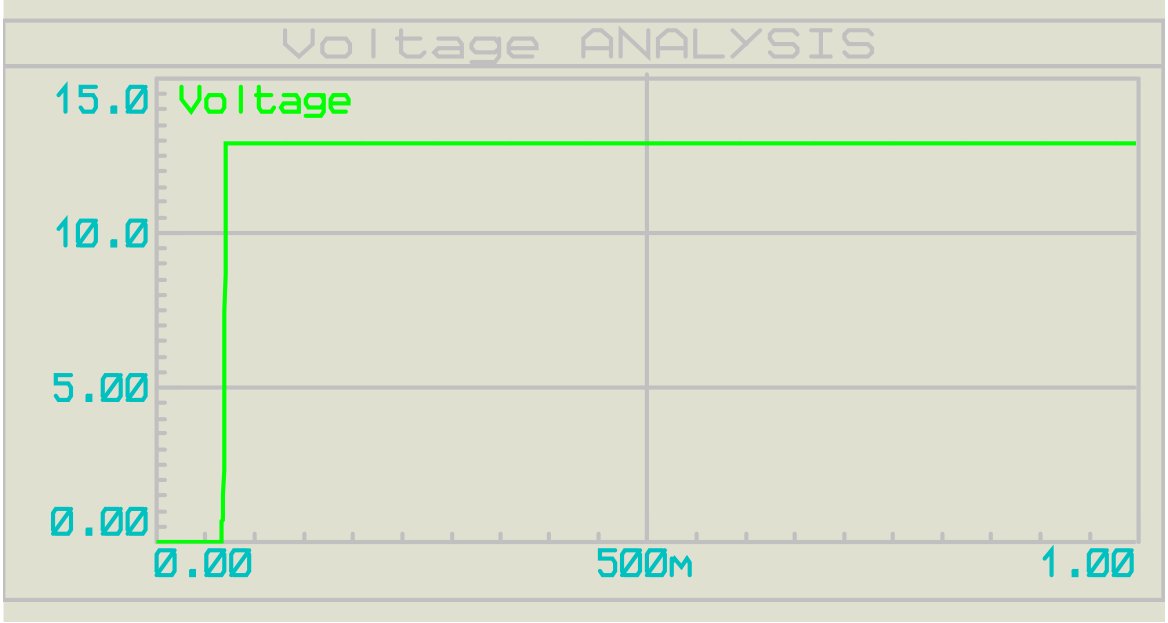


Figure 7.4: Final Result Voltage Graph of EVs Simulation

The Voltage graph is shown in Figure 7.4. The y-axis shows the voltage values and the x-axis shows the simulation time values. The graph shows that the value of voltage rises straight up from 0.1 time point to 14.5 volt. So we can see from the graph that the output value of voltage is 14.5 volt. The model of the proposed paper is such that it is possible to increase or decrease the output voltage by reducing the duty cycle through variables. Since our lithium ion battery is 12 volts, we need to charge 20 percent more than the input voltage, so we have 14.5 outputs.

7.2 Discussion

A competent battery charger is the foundation for long-lasting and reliable batteries. Chargers are frequently given minimal importance and are seen as an "afterthought" in a price-sensitive market. Like a horse and carriage, the battery and charger must work together. Prudent planning prioritizes the power supply by placing it at the start of the project rather than after the hardware is finished, as is typical. The charging speed of a charger is a frequent way to identify it. When used as indicated, consumer devices come with a low-cost personal charger that works well. When lead-acid and nickel-based batteries are cold, they receive charge but at a slower rate.When storing the battery in a discharged state, where self-discharge brings the voltage to the cut-off threshold, a sleep situation can occur. A standard charger considers such a battery to be unusable, and the pack is frequently destroyed. The charge current is continuous, and when the voltage reaches a certain level, it is capped. The battery saturates when it reaches the voltage limit; the current reduces until the battery can no longer receive any more charge, and the fast charge is terminated. The low-current threshold varies each battery.

Utilities should be able to handle the loads associated with charging EV batteries. Furthermore, coordinated or "smart" charging is critical for mitigating the negative implications of EV uptake on power infrastructures. Controlled charging is an open research topic that is actively being investigated. Finally, the test bed, which was created using a real-time digital simulator, can be utilized to conduct various distribution system research, such as voltage reduction approaches.

CHAPTER 8

CONCLUSION

8.1 Conclusion

The goal of this project is to create a battery cell testing platform and to simulate Lithium Ion (Li-Ion) batteries for electric vehicles. A revolutionary regenerative and programmable cell testing device is being developed as a viable option for testing automated grade batteries in real-world drive-cycle patterns. To precisely estimate battery performance, a unique battery modeling approach is proposed. The proposed model is meant to be used in real-time BMS systems to improve vehicle performance even more. The model is also used to evaluate the long-term impact of battery impedance on EVs performance in real-world engine loads.As electric vehicles have gained traction and a presence on the political agenda in recent years, our work has recorded the process. The research primarily focused on the steps taken to bring electric vehicles into public vehicle fleets and public transportation services, as well as the political and practical prerequisites for adopting plug-in electric vehicles into Swedish energy and transportation networks. The work's interdisciplinary approach yielded results on the utilization of plug-in electric vehicles that go beyond a standard technical explanation of empirical data and shift the narrative point of view.

8.2 Future Work

In view of the introduced research work in this theory, the accompanying ideas are accommodated further investigations:

- Utilizing the multi-channel testing stage, the impact of encompassing temperature, normal current and current profiles on life season of Li-Particle batteries can be dissected by performing limit estimations tests on the batteries after a specific number of cycles.
- The battery model can be additionally improved by coordinating the impact of debasement. The model boundaries can be estimated extra time (at various number of cycles). The model boundaries can then be refreshed powerfully founded on SOC, battery temperature and corruption.

- The exhibition of the battery pack, examined in Part 4, can be improved by considering befuddles among the battery cells and the non-consistency of the temperature appropriation in the phone, module and battery pack. Nonetheless, this can additionally entangle the estimations that ought to be finished by the EVs continuously.

References

[1] TESLARATI, "History Lesson: The evolution of the electric car [Infographic]," 7 November 2017. [Online]. Available: https://www.teslarati.com/history-lessonevolution-electric-car-infographic/. [Accessed 11 September 2021].

[2] T. D. Sun, "Sales of Electric Cars in Hungary Multiplied By Five," 9 March 2019. [Online]. Available:http://www.debrecensun.hu/eco/2018/03/09/sales-of-electric-carsin-hungary-multiplied-by-five/. [Accessed 29 April 2021].

[3] K. I. S. a. L. P. CsabaFarkas, "Impact assessment of electric vehicle charging on a LV distribution system," in *3rd International Youth Conference on Energetics (IYCE),*Leiria, 2011.

[4] M. I. A. S. S. (. I. ANAMIKA DUBEY, "Electric Vehicle Charging on Residential Distribution Systems: Impacts and Mitigations," IEEE Access, vol. 3, pp. 1871 - 1893, 2015.

[5] Tsiropoulos I., Tarvydas D., Lebedeva N., "Li-ion batteries for mobility and stationary storage applications – Scenarios for costs and market growth", EUR 29440 EN, Publications Office of the European Union, Luxembourg, 2018, doi:10.2760/87175.

[6] Cao, J., Schofield, N., &Emadi, A., "Battery balancing methods: A comprehensive review," IEEE Vehicle Power and Propulsion Conference, 1-6, Harbin, 2008.

[7] Bentley, W. F., "Cell balancing considerations for lithium-ion battery systems," 12th Annual Battery Conference on Applications and Advances, 223-226, California, 1997.

[8] Kutkut, N. H., & Divan, D. M., "Dynamic Equalization Techniques for Series Battery Stacks," IEEE Telecommunications Energy Conference, INTELEC '96, pp. 514-521, Boston, 1996.

[9] Moore, S. & Schneider, P., "A Review of Cell Equalization Methods for Lithium Ion and Lithium Polymer Battery Systems," in Proceedings of the SAE 2001 World Congress, 2001.

[10] Thomas, A., & Zhu, W., "Fast Equalization for Large Lithium Ion Batteries," IEEE Aerospace and Electronic Systems Magazine, 24, 27-31, 2009.

[11] Daowd, M., Omar N., Bossche, P. V. D., Mierlo, J. V., "Passive and Active Battery Balancing comparison based on MATLAB Simulation", Vehicle Power and Propulsion Conference, 978-1-61284, Chicago, 2011.

[12] Farmann, A. ve Sauer, D. U. “A comprehensive review of on-board State-ofAvailable-Power prediction techniques for lithium-ion batteries in electric vehicles” Journal of Power Sources, 329, 123-137, 2016.

[13] Saw, L.H., Ye, Y. veTay, A.A.O. “Electro-thermal analysis and integration issues of lithium ion battery for electric vehicles” Applied Energy, 131, 97-107, 2014.

[14] Lagraoui, M., Doubabi, S. veRachid, A. “SOC estimation of Lithium-ion battery using Kalman filter and Luenberger observer: A comparative study”, In 2014 International Renewable and Sustainable Energy Conference (IRSEC). 636-641, Ouarzazate, 2014.

[15] Phung, T. H., Crebier, J. C., Chureau, A., Collet, A., & Nguyen, N. T. “Optimized Structure for Next-to-Next Balancing of Series- Connected Lithiumion Cells,” 26th Annual IEEE Applied Power Electronics Conference and Exposition (APEC), 1374-1381, Texas, 2011.

[16] Sang-Hyun, P., Tae-Sung, K., Jin-Sik, P., Gun-Woo, M., &Myung- Joong, Y., “A New Battery Equalizer Based on Buck-boost Topology” IEEE 7th International Conf. on Power Electronics, Bangkok, 962-965, 2007

[17] Moo, C.S., Hsieh, Y.C., Tsai, I.S. & Cheng, J.C., “Dynamic Charge Equalisation for Series-Connected Batteries,” IEEE Proceedings Electric Power Applications, 150(5), 501-505, 2003.

[18] Imtiaz, A., Khan, F., & Kamath, H., “A Low-Cost Time-Shared Cell Balancing Technique for Future Lithium-Ion Battery Storage System Featuring

[19] Lin, S.L., Huang, K.L., Wang, I.C., Chou, I.C., Kuo, Y.M., Hung, C.H. & Lin, C., “Characterization of spent nickel–metal hydride batteries and a preliminary economic evaluation of the recovery processes” Journal of the Air & Waste Management Association. 66(3), 296-306, 2016

[20] Farmann, A. & Sauer, D. U., “A comprehensive review of on-board State-ofAvailable-Power prediction techniques for lithium-ion batteries in electric vehicles” Journal of Power Sources. 329, 123-137, 2016

[21] Nugroho, A., Rijanto, E., Wijaya, F.D. &Nugroho, P., “Battery state of charge estimation by using a combination of Coulomb Counting and dynamic model with adjusted gain”, In Sustainable Energy Engineering and Application (ICSEEA), 2015 International Conference on, 54-58, 2015

[22] Pastor-Fernandez, C., Bruen, T., Widanage, W.D., Gama-Valdez, M.A. & Marco, J. “A study of cell-to-cell interactions and degradation in parallel strings: implications for the battery management system” Journal of Power Sources, 329, 574-585, 2016

[23] Zhang, X., Liu, P., & Wang, D., “The Design and Implementation of Smart
[24] Battery Management System Balance Technology,” Journal of Convergence Information Technology, 6(5), 108-116, 2011

[25] Kutkut, N., Wıegman, H. L. N., Divan, D., Novotny, W., “Charge Equalization for An Electric Vehicle Battery System” IEEE Transactions on Aerospace and Electronic Systems 34(1), 1998

[26] Taiwan, Y., & Taiwan, G., “ZCS Bi-directional DC-to-DC Converter Application in Battery Equalixation for Electric Vehicles”, 35th Annual IEEE Power Elecrronics Specialists Conference, Aachen, 2004

[27] Young, C.M., Chu, N.Y., Chen, L.R., Hsiao, Y.C., Li, C.Z., IEEE Transactions on Industrial Electronics 60, 1972-1978, 2013

[28] Moghaddam, A., Van den Bossche, A., “A Smart High-Voltage Cell Detecting and Equalizing Circuit for LiFePO4Batteries in Electric Vehicles”, Applied Sciences,9(5391), 1-15, 2019

[29] "The Next Generation of Hybrid Cars: Plug-in Hybrids Can Help Reduce Global Warming and Slash Oil Dependency," N. R. D. Council, Ed., ed, July 2007, p. 4.

[30] M. Etezadi-Amoli, K. Choma, and J. Stefani, "Rapid-charge electric-vehicle stations," IEEE Transactions on Power Delivery, vol. 25, pp. 1883-1887, 2010.

[31] Z. Darabi and M. Ferdowsi, "Aggregated Impact of Plug-in Hybrid Electric Vehicles on Electricity Demand Profile," Sustainable Energy, IEEE Transactions on, vol. 2, pp. 501508, 2011.

[32] International Energy Agency (IEA) and the Electric Vehicles Initiative of the Clean Energy Ministerial (EVI), "GLOBAL EV OUTLOOK: Understanding the Electric Vehicle Landscape to 2020," April 2013.

[33] C. H. Stephan and J. Sullivan, "Environmental and energy implications of plug-in hybridelectric vehicles," Environmental Science and Technology, vol. 42, pp. 1185-1190, 2008.

[34] C. Farmer, P. Hines, J. Dowds, and S. Blumsack, "Modeling the impact of increasing PHEV loads on the distribution infrastructure," in 43rd Annual Hawaii International Conference on System Sciences, HICSS-43, January 5, 2010 - January 8, 2010, Koloa, Kauai, HI, United states, 2010, p. Shidler College of Business; University of Hawai'i.

[35] K. Young, C. Wang, and K. Strunz, "Electric Vehicle Battery Technologies," in Electric Vehicle Integration into Modern Power Networks, ed: Springer, 2013, pp. 15-56.

[36] Dubey, G.K. (1989) Power Semiconductor Controlled Drives, Prentice-Hall, Englewood Cliffs, NJ.

[37] Novotny, D.W. and Lipo, T.A. (1996) Vector Control and Dynamics of AC Drives, Oxford University Press, Oxford.

[38] Sul, S.-K. (2011) Control of Electric Machine Drive Systems, Wiley-IEEE Press, Hoboken, NJ.

[39] Vas, P. (1998) Sensorless Vector and Direct Torque Control, Oxford University Press, Oxford.

[40] Bose, B.K. (2001) Modern Power Electronics and AC Drives, Prentice-Hall, Upper Saddle River, NJ.

Appendix
Code:

```
#include <Arduino.h>

//Analog input pin for the potentiometer
intpotentiometer_pin = A1;

float sensorValue1 = 0;
floatvoltageValue = 0;
floatcurrentValue = 0;
// PWM output pin
intpwm_pin = 5;


void setup() {
  // Adjusts the pin to input mode
Serial.begin(9600);
pinMode(potentiometer_pin, INPUT);
  // Adjusts the pin to output mode
pinMode(pwm_pin, OUTPUT);

  // Adjusts the PWM frequency to 980.39 Hz.
  // By default arduino PWM frequency is
490.20 Hz,
  // but this value is not high enough to have a
stable DC output voltage in low duty cycles.
  TCCR2B = TCCR0B & B11111000 |
B00000011;
}

void loop() {

  // Reads the voltage of the potentiometer to a
value between 0 to 1023
  // The resolution of ADC on Arduino is 10
bits.
intduty_cycle =
analogRead(potentiometer_pin);

  // Maps the value from [0 1023] to [0 255]
for the PWM function of Arduino
intduty_cycle_mapped = map(duty_cycle,
0, 1024, 0, 254);

Serial.print("duty_cycle_mapped = ");
Serial.println(duty_cycle_mapped);

  sensorValue1 = analogRead(A0);
voltageValue = (sensorValue1 * 5.0 /
1023.0) * 5;

if (voltageValue<= 7.4 &&voltageValue>=
7)
  {
Serial.print("Voltage = ");
Serial.println(voltageValue);
duty_cycle_mapped = 0;
  }

  // Sets the PWM signal duty cyle value, 0-
>0%, 254->100%
analogWrite(pwm_pin,
duty_cycle_mapped);
}
```